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# Abundance, Age, Size, Sex and Coded Wire Tag Recoveries for Chinook Salmon Escapements of Campbell and Quinsam Rivers, 1985

J.H. Andrew, M. Lightly and T.M. Webb

Department of Fisheries and Oceans
Fisheries Branch
#416, Suite 400 - 555 West Hastings Street
Vancouver, British Columbia V6B 5G3

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# ABUNDANCE, AGE, SIZE, SEX AND CODED WIRE TAG RECOVERIES FOR CHINOOK SALMON ESCAPEMENTS OF CAMPBELL AND QUINSAM RIVERS, 1985

by

J.H. Andrew[1], M. Lightly[2] and T.M. Webb[1]
Department of Fisheries and Oceans
Fisheries Branch
#416, Suite 400 - 555 West Hastings Street
Vancouver, British Columbia
V6B 5G3

[1]ESSA Environmental and Social Systems Analysts Ltd.
Box 12155 - Nelson Square
Suite 705 - 808 Nelson Street
Vancouver, British Columbia
V6Z 2H2

[2]Islands Biological Group
R.R. # 2, Site 20A
Gabriola, British Columbia
V0R 1X0

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## ABSTRACT

Andrew, J.H., M. Lightly and T.M. Webb. 1988. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1985. Can. MS Rep. Fish. Aquat. Sci. 2007: 46 p.

Intensive spawning ground surveys were conducted on the Campbell and Quinsam rivers in 1985 as part of the chinook key stream program. The Petersen carcass tagging estimate of chinook escapement to the Campbell River was 1,427 $\pm$ 201 fish (95% CL) and to the Quinsam River was 1,590 $\pm$ 175 fish (95% CL). In both rivers, males predominated at age $4_1$ and females at age $5_1$. Estimated escapements by age are presented.

There were 78 adipose marked chinooks in the Campbell dead recovery and 237 in the Quinsam. Escapements of adipose clipped chinooks, based on these recoveries, were 160 to the Campbell and 393 to the Quinsam. these are presented by age, sex and individual tag code. The total hatchery contribution to the escapements were estimated using coded wire tagged/adipose mark rates at release. In the Campbell, the hatchery contributed 38.9% of the male chinook escapement and 50.3% of the female escapement. In the Quinsam, the hatchery contributed 72.2% of the male and 80.3% of the female escapement.

Key Words: Quinsam, Campbell, chinook, key stream, escapement, coded wire tags, age composition, hatchery, carcass tagging.

## RÉSUMÉ

Andrew, J.H., M. Lightly and T.M. Webb. 1988. Abundance, age, size, sex and coded wire tag recoveries for chinook salmon escapements of Campbell and Quinsam rivers, 1985. Can. MS Rep. Fish. Aquat. Sci. 2007: 46 p.

Des relevés détaillés des frayères des rivières Campbell et Quinsam ont été réalisés en 1985 dans le cadre du programme des cours d'eau les plus importants pour le saumon quinnat. Les valeurs estimées des échappées, par la méthode Petersen de marquage et de récupération des carcasses, ont été de 1,427 $\pm$ 201 poissons (LC 95%) dans la rivière Campbell et de 1,590 $\pm$ 175 poissons (LC 95%) dans la rivière Quinsam. Dans les deux cours d'eau, les mâles d'âge $4_1$ et les femelles d'âge $5_1$ étaient les plus nombreux. Les auteurs présentent les échappées estimeés par groupes d'âges.

Les carcasses de 78 saumons quinnats marqués à la nageoire adipeuse ont été récupérées dans la rivière Campbell et celles de 237 l'ont été dans la rivière Quinsam. Si l'on se base sur ces valeurs, les échappées de saumons quinnats marqués à la nageoire adipeuse on été de 160 dans la rivière Campbell et de 393 dans la rivière Quinsam. Les valeurs obtenues sont ventilées par âges, sexes et codes. L'apport total des poissons de pisciculture aux échappées a été estimé à partir du rapport entre les poissons marqués par fils codés et ceux marqués par coupure de la nageoire adipeuse au moment de la mise à l'eau. Dans la rivière Campbell, les poissons d'élevage représentaient 38.9% de l'échappée des quinnats mâles et 50.3% de celle des femelles. Dans la rivière Quinsam, ces valeurs étaient respectivement de 72.2% et de 80.3%.

Mots clés: Quinsam, Campbell, quinnat, cours d'eau principal, échappée, étiquettes en fils codés, composition par âge, pisciculture, carcasses marquées.

## INTRODUCTION

The chinook salmon of the Campbell/Quinsam river system was selected as one of the indicator stocks for assessing the response of Pacific chinook salmon stocks to a new harvest management regime. The goal of the new management regime is to rebuild chinook stocks to historical levels. This "key stream" program began in 1984 in response to objectives set out in the Canada - U.S. Salmon treaty.

The major objectives of the key stream program are:

1) to accurately estimate chinook escapement on key streams;

2) to estimate harvest rates and contributions to fisheries and escapement based on coded wire tagged/adipose clip returns, including estimates of the total escapement of coded wire tags to the key streams system; and

3) to estimate the contribution of hatchery and natural production to the escapement.

Chinook escapements to Campbell River have ranged from 750 to 8,000 since 1947 (Shardlow et al. 1986). Chinook escapement to the Quinsam River was negligible prior to the opening of Quinsam Hatchery in 1972, but has ranged from 1,000 to 2,000 in recent years.

This paper presents the results of the second year (1985) of intense escapement monitoring and sampling of chinook salmon in the Campbell/Quinsam system (see Shardlow et al. 1986 for 1984 study results). The 1985 escapement was calculated by the adjusted Petersen method by tagging carcasses to produce separate estimates for sexes and rivers and summing these to form a total estimate. Potential biases in the Petersen method, carcass tagging method, and method of stratification are discussed. Assumptions for the methods used and the tests for biases caused by violations of assumptions are described in the methods section. The results section presents the population estimates, tests for bias in tagging and recovery, population composition (age, length, and sex) and the results of coded wire tag studies. The results are then discussed with respect to other studies and recommendations are made regarding future studies.

To avoid confusion in terminology relating to tagging and marking, the word "tagging" as used in this report refers to electrical strap tagging and "marking" refers to marking of chinook juveniles with coded wire tags and clipped adipose fins.

## STUDY AREA

Campbell River originates east of the Vancouver Island Ranges and flows in an easterly direction for 9 km into Discovery Passage immediately north of the city of Campbell River, British Columbia (Fig. 1). Quinsam River, a major tributary of Campbell River, flows in a northerly direction through a series of small lakes for approximately 30 km to its confluence with the main Campbell River approximately 3.8 km upstream of its mouth.

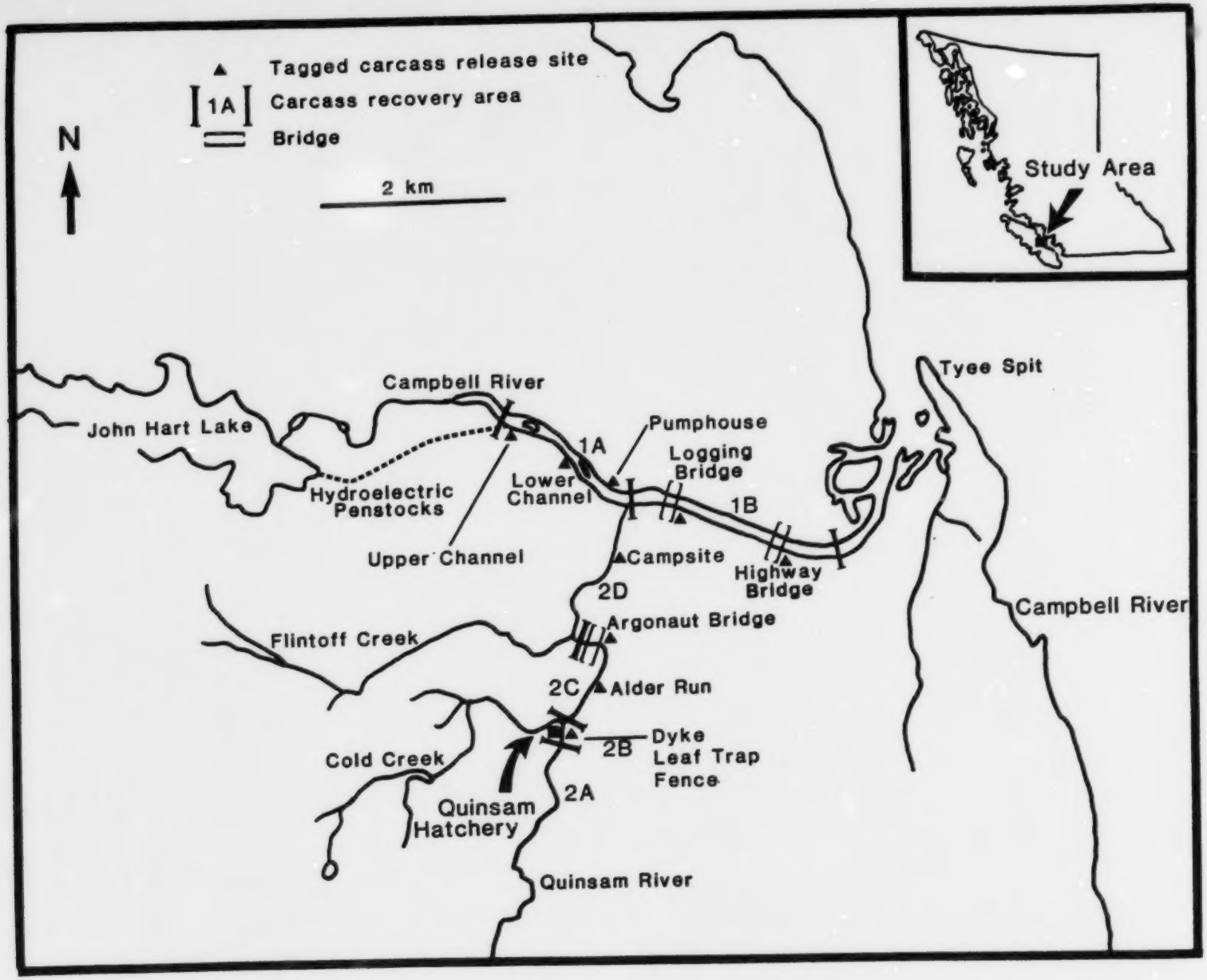


Figure 1. Map of the Campbell and Quinsam rivers study area, 1985.

The drainage area of the Campbell River system is 1,460 $km^2$ and of the Quinsam River system is 265 $km^2$. Fish passage in Campbell River is blocked by natural falls and a hydroelectric dam 5.5 km upstream of the mouth. Approximately 27 km of the Quinsam are accessible to natural spawning but most chinook spawning usually takes place in the lower 4 km of the river (Shardlow et al. 1986).

Flows in the Campbell River are controlled by the John Hart Generating Station, located 5.5 km upstream of the mouth (Marshall et al. 1977) and vary from 1.2 $m^3s^{-1}$ to 826.0 $m^3s^{-1}$ (mean=96.0 $m^3s^{-1}$). The hydroelectric development also includes a diversion dam constructed in 1957 and storage dams completed in 1947. The effects of modified hydrology on salmonids in Campbell River has been studied (Hamilton and Buell 1976). Mineral mining is conducted in the headwaters of the Campbell, and forestry harvesting in the vicinity of the large lakes in the watershed (J. Van Tine, Manager of Quinsam Hatchery, Box 467, Campbell River, British Columbia, pers. comm., 1988). Commercial development in the Campbell River estuary includes log booming, sawmills, shake mills, a seaplane base at Tyee Spit, and pleasure boat moorage. Manmade islands have been constructed in the estuary in an effort to improve fish habitat (Levings 1986). The community of Campbell River (population approximately 18,000) surrounds the lower 2 km of the river. Access to the Campbell is primarily by municipal roads and by the Campbell River Road, which runs along the south bank of the river.

Flows on the Quinsam are not controlled and vary from 0.9 $m^3s^{-1}$ to 21.6 $m^3s^{-1}$ (mean=9.$m^3s^{-1}$) (Shardlow et al. 1986). Mining for coal is conducted in the headwaters of the Quinsam, and forest harvesting is conducted throughout the watershed (J. Van Tine, pers. comm., 1988). There is easy access to the lower reaches of Quinsam River but upstream of the hatchery, access is more difficult (i.e. logging roads).

The Campbell/Quinsam river system supports four species of Pacific salmon as well as steelhead trout (Salmo gairdneri); in order of abundance the salmon species are pink, chinook, chum and coho salmon (Oncorhynchus gorbuscha, O. tshawytscha, O. keta and O.kisutch, respectively). Chinook spawn in Campbell River upstream of the confluence with the Quinsam, and in the Quinsam from the mouth to the counting fence. Coho spawn in the Quinsam River but not the Campbell, and chum and pink salmon spawn in the lower reaches of the Campbell only. Chinook start migrating into the Campbell in late August but mainly in October, and spawn from mid-October to mid-November, with peak spawning in early November (J. Van Tine, pers. comm., 1988). Migration of chinook into the Quinsam is greatly influenced by rainfall, but usually occurs from late September to early October. Spawning is usually completed by late November.

Quinsam Hatchery is located approximately 3.7 km upstream of the confluence with the Campbell River. A fence is located immediately upstream of the hatchery for broodstock collection (Fig. 1). Fish distribution and smolt production as well as river flows and water quality in the watershed was studied by Blackmun et al. (1985).

Fisheries on Campbell/Quinsam chinook stocks include sport and commercial fisheries. Ocean sport fishing is relatively heavy (Marshall et

al. 1977), but the rivers are closed to sport fishing of chinook. Within the rivers, coho salmon as well as sea run and resident trout are captured in the sport fishery. Both the Alaskan and Canadian commercial fisheries capture Campbell/Quinsam chinook stocks.

## METHODS

Field work was conducted from mid-October to mid-December by Quinsam Hatchery workers. A summary of methods for this study is presented in Table 1 and is described below.

### POPULATION ESTIMATION

Chinook salmon were enumerated by the adjusted Petersen method (Ricker 1975, p. 78) using carcass tagging of hatchery broodstock and recovery of tags from carcasses following natural spawning. Although the tagging and recovery programs were designed for either the Petersen or Schaefer methods, only the Petersen results are presented as there were insufficient recoveries to calculate Schaefer estimates for separate sexes. However, preliminary analysis showed that the Schaefer estimate for the whole population fell within the 95% confidence limits of the Petersen estimate calculated by summing estimates for sexes separate.

#### Population Stratification

There are four main ways of stratifying the tagging and dead recovery data to produce a Petersen estimate:

1) sexes and rivers pooled;

2) sexes separate with rivers pooled;

3) sexes separate and rivers separate; and

4) sexes pooled with rivers separate.

Separate Petersen estimates may be calculated for each stratum and then summed to obtain an estimate of the whole population. By segregating the data into separate population strata, biases created by factors which affect the strata at different rates may be circumvented. The main factors of concern are rates of tag application, recovery of carcasses, and tag loss.

If carcasses in the Campbell and Quinsam rivers do not mix following release of tagged carcasses in each river, forming two distinct groups for the purposed of enumeration, then there is a potential for substantial bias in unstratified estimates if tagging or dead recovery rates and effort are not identical.

Due to the likelihood of factors affecting sexes and rivers at different rates, Petersen estimates were stratified by sex and river in this study.

#### Potential Biases

Within a stratum, Petersen estimates using carcass tagging are

Table 1. Summary of methods for Campbell and Quinsam rivers chinook salmon enumeration programs, 1985.

| Item | Method or materials[a] |
|---|---|
| Population enumeration | Petersen estimate, sum of separate estimates for sexes and rivers |
| Tagging | Electrical strap tags |
| Secondary marking | Double tags in one tag group of 50 fish |
| Recovery of fish | Foot, boat and SCUBA surveys |
| CWT[a] tagging | Releases in 1979 to 1982; adipose clipped to flag presence of a CWT |
| CWT recovery | Collection of heads from adipose clipped fish in the dead recovery |
| Biological and physical sampling | Ages from scales<br>Sex ratios from sexes separate population estimates for each river<br>Postorbital-hypural length (mm)<br>Stream discharge - Water Survey of Canada |

[a] CWT = coded wire tag

potentially biased by violation of a number of assumptions. Seven of these assumptions, as modified from Ricker (1975, p. 81-82) are presented below along with the consequences of violating them.

Tests used to determine whether biases were acting in this study are also presented and discussed below with respect to sex and river stratification of the Petersen estimate. Certain biases caused by methods of tagging, recovery, age determination, etc. are discussed in subsequent sections.

1) Tags are consistently applied in proportion to the available population and/or the distribution of recovery effort is proportional to the number of fish present in different river reaches and/or tagged fish become randomly mixed with untagged fish.

To obtain an accurate Petersen estimate, it is important to apply and/or recover tags in proportion to the available population. In this study, tagged hatchery carcasses were released in river reaches in proportion to the available population as assessed by a preliminary foot survey of the distribution of natural carcasses in the two rivers before the carcass recovery operation began. However, there was no independent measure of the numbers of fish available for dead recovery, nor of the timing of the migration and termination of spawning. This is a fairly important problem as it affects the representativeness of sampling.

A related problem associated with rivers-separate escapement estimates is that tagged fish may stray between rivers. Apart from movement due to washout, tagged carcasses are not subject to straying in the same way as live fish. Calculations related to straying are described below. It is not possible to statistically test the extent of mixing of marked and unmarked fish using the data from this study, but movements of tagged fish are indicated by the location of recovery relative to the location of tagging. Tag release and recovery locations were grouped into river reaches to facilitate this comparison.

2) There is a negligible influx of spawners after the conclusion of tagging.

An influx of spawners following tagging could cause the Petersen calculations to overestimate or underestimate the true population depending on how they mixed with tagged fish. The tagging program was designed to release tagged carcasses in four time periods as spawners migrated into the rivers. However, it is not possible to test this assumption with the data from this study.

3) There is no tag loss.

A high incidence of tag loss will cause Petersen calculations to overestimate the true population. Tag loss was determined by double tagging one group of fifty fish with tags of a particular colour and comparing the recoveries of double and single tagged carcasses of that colour.

4) All tags are recognized and reported on recovery after the conclusion of tagging.

In this study, no repitches were conducted to reexamine carcasses for missed tags and secondary marks, therefore it was not possible to evaluate tag non-reporting incidence.

5) Recovery efforts are made on the same population as was tagged.

Dead recovery from a population other than the tagged population will cause Petersen calculations to overestimate the true population. Indications that tagging and recovery were conducted on different populations would be different age frequency and length frequency distributions among the two samples. Data were not taken to perform these tests.

6) There is adequate sampling to obtain a tag recovery rate which provides an accurate and precise population estimate.

A small number of tag recoveries in a stratum will cause Petersen estimates to have low precision. Petersen estimates are generally more reliable if a high proportion of the tagged fish are recovered in each stratum. In the absence of other sources of bias, approximately 25 to 75 recaptures will produce population estimates with 25% accuracy, with 95% confidence, for populations of $10^2$ and $10^9$ (Ricker 1975). Confidence intervals for the escapement estimates were calculated as described later in the calculations section of the methods.

7) Tagged carcasses are representative of the population and behave in a similar manner to untagged carcasses with respect to buoyancy, visibility, and decomposition.

Tagged carcass recoveries will not be representative of the population if tagged carcasses do not mix completely with untagged ones, in which case the Petersen method may overestimate or underestimate the population. The thoroughness of mixing depends on how tagged carcasses are placed into the river and whether carcasses behave in a similar manner to untagged carcasses. It is not possible to statistically test the assumption of mixing with the data from this study. However, comparisons were made of tagging and recovery reaches of tagged fish.

Buoyancy and decomposition may be important factors causing differential behaviour of tagged and untagged carcasses especially if tagged carcasses become bloated with air during handling. Differences in tag visibility could cause preferential sampling of tagged carcasses, and result in an underestimate of the population. An attempt was made to circumvent this problem by using neutral colours to prevent increased visibility of tagged carcasses. It is not possible to test the assumption of similar visibility between tagged and untagged carcasses with the data from this study. The assumption of similar buoyancy and decomposition of tagged and untagged carcasses could be tested by comparing the tag recovery rate in the dead recovery with the rate at carcass weirs if such data were available.

Calculations

The Petersen estimate of each stratum was calculated as follows (Chapman's formula, cited in Ricker 1975, p. 78):

$$\text{Petersen estimate} = \text{Total fish in dead pitch} + 1 \times \frac{(\text{Total fish tagged} + 1)}{\text{Total tagged fish recovered} + 1}$$

Population estimates for sex and river strata were summed to obtain a total population estimate. For purposes of these calculations, tagged or recovered adults of unknown sex were assumed to be 50:50 males and females.

Confidence limits for the toal population estimate were determined by first calculating the variance of the estimate of each stratum as follows:

$$VAR_{m,c} = \frac{(PE_{m,c})2(TA_{m,c} - TR_{m,c})}{(TA_{m,c} + 1)\,(TR_{m,c} + 2)} \qquad \text{(Ricker 1975, p. 78)}$$

determining the total variance by summing the variances of strata as follows:

$$VAR_{t,c} = VAR_{m,c} + VAR_{f,c} + VAR_{j,c}$$

and applying this figure in the calculation of the 95% confidence interval for the total population estimate as follows:

$$\text{Upper and lower 95\% confidence limits of } PE_{t,c} = PE_{t,c} \pm 1.96 \sqrt{VAR_{t,c}}$$

where VAR = variance of the population estimate
PE = Petersen estimate
DR = dead recovery
TA = tags applied
TR = tag and tag loss recovery
m,c = Campbell River male stratum
f,c = Campbell River female stratum
j,c = Campbell River jack stratum
t,c = total Campbell River males, females, and jacks

A similar methodology was used to calculate the 95% confidence limits for the total escapement of each sex.

Strays

In this study, tagged carcasses released in one river and recovered in the oriver were considered to be strays. For purposes of the Petersen calculation, a calculation of tagged strays was made using the number of

tagged strays observed divided by the dead recovery rate was calculated using rivers pooled and sexes separate data. The number of tagged fish available in each of the Campbell and Quinsam dead recovery programs was calculated by taking the number of tagged fish released in each location and subtracting the number of tagged strays that moved to the opposite portion of the river and adding the number of tagged strays that arrived from the opposite location. The calculations were performed as follows:

$$\text{Tagged strays from Quinsam River (expanded)} = \text{Number tagged strays from Quinsam River in dead pitch} \times \frac{1}{\text{Dead recovery rate}}$$

where

$$\text{Dead recovery rate} = \frac{\text{Total recovered}}{\text{Total population}}$$

and total population was derived from Chapman's formula in Ricker (1975, p. 78) and lastly,

$$\text{Tagged fish available in Campbell} = \text{Tags released in Campbell} + \text{Tagged strays from Quinsam to Campbell} - \text{Tagged strays from Campbell to Quinsam}$$

The Petersen calculation was then performed using the calculated tagged fish available in the Petersen equation given earlier.

TAGGING

Tagging was conducted by a crew of one or two hatchery workers. Tagged carcasses were released on four separate dates in each river (Table 2). Releases were made at four sites in Campbell River and seven sites in Quinsam River to achieve a tag release number of 50 fish per river per occasion (Appendices 1 and 2; Fig. 1). The distribution of tag releases was designed to match that of the spawning population which was ascertained by a foot survey of carcasses of both rivers prior to commencing the dead recovery program.

Carcasses from Quinsam Hatchery broodstock were tagged with electricial strap tags which were painted neutral colours nad attached around the lower jaw bone of the carcass. Two tags were applied to 50 carcasses in the Quinsam black/grey tag group in order to assess tag loss.

RECOVERY

Hatchery crews that conducted dead recovery were composed of two to six workers each day. Approximately 44 person-days were spent in dead recovery effort over a period of 19 days in Campbell River and approximately 39 person-days were spent over a period of 19 days in the

Table 2. Summary of release of tagged chinook salmon carcasses in the Campbell and Quinsam rivers, 1985.

| River | Date | Tag colour | Number released | | | |
|---|---|---|---|---|---|---|
| | | | Males | Females | Jacks | Total |
| Campbell | October 31 | Brown | 30 | 14 | 6 | 50 |
| | November 6 | Blue | 24 | 21 | 5 | 50 |
| | November 12 | Green | 20 | 21 | 9 | 50 |
| | November 15 | Black | 28 | 21 | 1 | 50 |
| | Total | | 102 | 77 | 21 | 200 |
| Quinsam | October 31 | Black/green | 23 | 22 | 5 | 50 |
| | November 6 | Black/brown | 17 | 31 | 2 | 50 |
| | November 12 | Black/blue | 21 | 26 | 3 | 50 |
| | November 15 | Double black/grey | 23 | 24 | 3 | 50 |
| | Total | | 84 | 103 | 13 | 200 |

Quinsam. A total of 23 surveys were conducted in Campbell River and 13 were conducted in Quinsam River (Table 3).

Recovery crews were instructed to dead pitch and count all available carcasses and record and keep all strap tags. Crews were intentionally not informed as to where tagged carcasses had been released, so that they would not spend more time examining these areas than other ones for tagged carcasses. Dead chinook were recovered from the Campbell and Quinsam rivers by two methods: (1) recovery crews searched the banks and shallow reaches of the rivers on foot and from a boat; and (2) a SCUBA diver recovered carcasses from deep pools in the lower reaches of the Campbell and Quinsam rivers.

Each carcass was examined for the presence of an electrical strap tag and missing adipose fin. Heads were removed from adipose clipped fish for sampling of CWTs. Material collected from the carcasses is described in the biological and physical sampling methods section. All recovered chinook carcasses were cut in half to prevent repeat enumeration and sampling.

Calculations relating to dead recovery were as follows:

$$\text{Tag rate} = \frac{\text{Total tagged fish recovered}}{\text{Total dead recovered}}$$

$$\text{Tag recovery rate} = \frac{\text{Total tagged fish recovered}}{\text{Total tagged}}$$

CODED WIRE TAGGING AND RECOVERY

Juvenile chinook from the 1979, 1980, 1981 and 1982 brood years were marked with binary coded wire tags (CWT) described by Jefferts et al. (1963) using standard methods (Armstrong and Argue 1977). Adipose fins of coded wire tagged juveniles were clipped prior to release of the fish.

In the dead recovery program, adipose fin clips were used to flag the presence of CWTs in returning adults. Heads from a sample of adipose clipped fish recovered in the dead pitch were taken to the Quinsam Hatchery where CWTs were removed and decoded.

Estimating the total number of CWT returns from each of the brood years, and for each tag code is a three step process:

1) determining the appropriate samples and population strata to use for estimating the overall adipose clip rate (using either the mark rate at hatchery release or that found in the dead pitch or some combination of the two based on what is the most representative sample);

2) determining the proportion of the population examined to produce the observed number of adipose clips. This is then used

Table 3. Summary of dead recovery effort (number of surveys) on the Campbell and Quinsam rivers, 1985.

| Week | Campbell River | | Quinsam River | |
|---|---|---|---|---|
| | Surface | Diving | Surface | Diving |
| October 20-26 | 1[a] | | | |
| October 27 November 2 | 3 | 2 | 1[a] | |
| November 3-9 | 3 | 2 | 2 | 1 |
| November 10-16 | 2 | 1 | 2 | 1 |
| November 17-23 | 2 | 2 | 2 | |
| November 24-30 | 2 | | 2 | |
| December 1-7 | 2 | 1 | 1 | |
| December 8-14 | | | 1 | |
| Total | 15 | 8 | 11 | 2 |

[a] Partial survey only.

to calculate the total number of adipose clips estimated to be in the escapement; and

3) allocating the total number of adipose clips estimated to be in the escapement among the tag codes in proportion to those successfully decoded.

If we assume that the survival of unmarked hatchery fish was equal to or greater than that of marked fish, this method estimates the minimum hatchery contribution to the escapement.

Adipose clipped fish were enumerated separately for males and females in the Campbell and Quinsam rivers to correspond with the stratified Petersen estimates. The dead recovery samples were used to estimate the total number of adipose clipped fish in the escapement. Adipose clipped and decoded CWT recoveries at the hatchery rack were not used in the analysis because the hatchery rack sample was seriously biased towards young hatchery-derived males (J. Van Tine, pers. comm., 1988). The mark rate at the Quinsam Hatchery rack was higher than the mark rate of the spawning population because hatchery-derived spawners migrate to the hatchery with greater frequency than wild spawners. As young hatchery-derived spawners migrate to the hatchery more frequently than older hatchery stock, decoded CWTs from the rack sample were skewed to recent releases.

Given an estimate of the number of adipose clips escaping to the river, the escapement of each tag code can be estimated by allocation to tag codes based on their relative frequency in the sample of decoded tags. This scheme of first estimating adipose clipped fish and then allocating these among the successfully decoded CWTs assumes that the lost pin/no pin fish in the sample represent fish that were once marked but lost their CWT for some reason. If this assumption is incorrect, the calculated number of hatchery origin fish would be biased upwards. It is possible, especially in the dead pitch, that some fish identified as hatchery releases by missing adipose fins may be natural fish that have lost their adipose fins through some other means, e.g. carcass decomposition. If decomposition of adipose fins is occurring then the adipose clip rate in the dead pitch should be higher than that observed in tagging. Data were not available to perform such a test.

The hatchery contribution to the escapement was calculated by comparing the escapement of each tag code with the total escapement broken down by age class.

Due to the potentially different ages at maturity of males and females, it is important that allocation of adipose clipped fish to tag codes is carried out separately by sex whenever possible. The sex of most fish sampled for CWTs was recorded so that it was possible to estimate the total escapement of tag codes by sex; adults of unknown sex were allocated equally between males and females in the Quinsam sample. Due to small sample sizes, the recoveries of jacks were excluded from this analysis.

BIOLOGICAL AND PHYSICAL SAMPLING

Biological sampling during dead recovery included scales for age determination, length, sex, tag colour if a tag was present, presence of a double tag, and presence of an adipose clip. Postorbital-hypural length was recorded from three out of four unmarked carcasses in the Campbell and every fourth carcass in the Quinsam, as well as from every adipose clipped fish. Males were considered to be jacks when their weight was less than approximately 4.5 kg. Scale samples were taken from the same fish as length samples, including all adipose clipped fish. A scraping of scales was placed in a labelled plastic envelope and the individual scales from each fish were mounted in scale books at the hatchery. Scales were aged at the Department of Fisheries and Oceans scale laboratory in Vancouver. Heads were removed from adipose clipped fish and saved for CWT extraction and decoding.

Ages were read only when a portion of the previous annulus was present and scales were not regenerated. Scales were classified as unreadable if the scales had regenerate centres, they were resorbed, or if they were mounted upside down. Ages were recorded for fish for which there were at least two scales that could be read for both marine and freshwater ages. In this report, the first numeral of the age recorded indicates the year of total life and second numeral (subscript) indicates the year of life in which the fish migrated to the ocean.

The age composition determined with the available samples is valid only if age sampling was random and there was no bias in readability of scales with age. Ages of older fish are usually more difficult to read than those of younger fish because scales of older fish usually undergo more resorption and regeneration. The data were examined for this potential bias using a t-test to compare the mean lengths of known and unknown age males and females.

The dead recovery sample was used to determine the age and length composition of the population. Samples of age and length taken from fish at the Quinsam hatchery rack were not included because this sample was seriously biased (see above). As marked (adipose clipped) fish in the dead recovery were sampled more intensively for age than unmarked fish, age compositions of the two groups were pooled after adjusting the age composition of marked fish by weighting the number of fish in each age class according to the mark rate in the dead recovery.

The population of each age class was then determined by allocating portions of the Petersen estimate to age classes according to the age composition determined from scale samples.

The sex ratio was determined for each river by sexes and rivers separate Petersen estimates. This method provides a valid sex ratio assuming that tag loss and tag recognition were not seriously biased by sex. The test for potential differences in tag loss was described in the tagging methods section. Tag recognition is not likely to be biased by sex; it is not possible to test this potential bias with the data in this study.

Stream flow data for the Campbell/Quinsam river system were

obtained from the Water Survey of Canada (Station 08HD005, Quinsam River near Campbell River).

## RESULTS

### TAGGING

Tagged carcasses were released on October 31 and November 6, 12, and 15 to five locations in Campbell River and seven locations in Quinsam River (Appendices 1 and 2, Fig. 1). A total of 102 males, 77 females and 21 jack carcasses were released into Campbell River and a total of 84 males, 103 females and 13 jacks were released into Quinsam River (Table 4).

All black/grey tags recovered were double, indicating that no tag loss occurred.

### RECOVERY

Surveys to recover carcasses began on October 23 in the Campbell and on October 30 in the Quinsam and continued until December 6 and 12, respectively (Appendices 3 and 4; Fig.1). Some reaches in each river were surveyed more frequently than others.

A total of 712 chinook carcasses were recovered in Campbell River (332 males, 362 females and 18 jacks; Table 4). This number included 98 tag recoveries (54 males, 38 females and 6 jacks), two (one female and one jack) of which were strays from Quinsam River. In Quinsam River, a total of 988 chinook carcasses were recovered (434 males, 512 females, 13 adults of unknown sex and 29 jacks; Table 4). This number included 116 tag recoveries (53 males, 56 females, one adult of unknown sex, and 6 jacks). In both rivers, more females than males were recovered, and fewer jacks were retrieved than either males or females.

As the tag colour did not indicate the location of release, it was not possible to determine the extent of mixing of tagged carcasses between river areas (within each river) to indicate the extent of mixing of tagged and untagged carcasses. However, the recovery of carcasses from each release date continued for at least two weeks. In the Campbell, tagged carcasses released on October 31 were recovered from November 1 to 15, those released on November 6 were recovered from November 7 to December 4, those released on November 12 were recovered from November 13 to December 4, and those released on November 15 were recovered from November 18 to December 4. Each tag colour (i.e. date of release) was recovered in both Areas 1A and 1B (Appendix 5 ), but the majority of fish (83.1%) were recovered in Area 1B, below the confluence with the Quinsam River (Appendix 5). In the Quinsam, tagged carcasses released on October 31 were recovered from November 5 to December 2, those released on November 6 were recovered from November 7 to 26, those released on November 12 were recovered from November 14 to December 12, and those released on November 15 were recovered from November 19 to December 11 (Appendix 6). Each tag colour was recovered in each of Areas 2B, 2C and 2D, but the majority of carcasses were recovered in the upper half of the river (65% were recovered in Areas 2B and 2C; Appendix 6).

The carcass tag recovery rate was higher in the Quinsam (58.0%;

Table 4. Summary of tagging and dead recovery of chinook salmon in Campbell and Quinsam rivers, 1985.[a]

| Item | Campbell | Quinsam | Total |
|---|---|---|---|
| Tagging Program | | | |
| Males tagged | 102 | 84 | 186 |
| Females tagged | 77 | 103 | 180 |
| Jacks tagged | 21 | 13 | 34 |
| Total tagged | 200 | 200 | 200 |
| Dead Recovery Program | | | |
| Males recovered | 332 | 434 | 766 |
| Females recovered | 362 | 512 | 874 |
| Unknown sex adults recovered | 0 | 13 | 13 |
| Jacks recovered | 18 | 29 | 47 |
| Total recovered | 712 | 988 | 1,700 |
| Tagged males recovered | 54 | 53 | 107 |
| Tagged females recovered | 38 | 56 | 94 |
| Tagged unknown sex adults recovered | 0 | 1 | 1 |
| Tagged jacks recovered | 6 | 6 | 12 |
| Total tagged fish recovered | 98 | 116 | 214 |
| Other[b] | | | |
| Tag rate | 13.8% | 11.7% | 12.6% |
| Tag recovery rate | 49.0% | 58.0% | 53.5% |
| Tag loss | - | 0.0%[c] | - |

[a] See raw data presented in Appendices 1-4.
[b] See text for method of calculation.
[c] As determined from one group of 50 fish that were double tagged.

Table 4) than in the Campbell (49.0%) but this difference was not significant (contingency $\chi^2$=1.51, df=1, p>0.05). There was a smaller difference when jack carcasses, which had a lower recovery rate, were omitted from the sample (contingency $\chi^2$=0.92, df=1, p>0.05). Within each river, the recovery rates of adult male and female tagged carcasses were not significantly different (Campbell: contingency $\chi^2$=0.11, df=1, p>0.05; Quinsam: contingency $\chi^2$=0.60, df=1, p>0.05).

POPULATION ESTIMATES

The chinook escapement to the Campbell was estimated at 1,427 fish, including 624 males, 735 females and 68 jacks (Table 5). In the Quinsam the escapement was 1,590 fish, including 651 males, 892 females and 47 jacks (Table 5). The total escapement for both systems was estimated at 3,017 ± 266 (95% CL). A summary of these escapement estimates and their confidence limits are presented in Table 6.

AGE, LENGTH AND SEX COMPOSITION

Scales from a total of 611 chinook carcasses from the Campbell and 417 from the Quinsam were examined for age. Of these, ages were determined for only 545 and 383 fish, respectively, as some scales were unreadable.

All of the fish sampled in the Campbell were ocean-reared (subones; Table 7). In the Quinsam, all were ocean-reared except one male aged $4_2$ and one female aged $5_2$ (Table 8). These fish had reared for one year in freshwater.

Ages of Campbell and Quinsam chinook ranged from $3_1$ to $7_1$ (Tables 7 and 8). Females were generally older than males; the predominant age class of males in both rivers (age $4_1$) was from the 1981 brood year and females (age $5_1$) was from the 1980 brood year.

Summaries of mean lengths by age are presented in Tables 7 and 8. Campbell River males and females (mean postorbital-hypural length males = 793.1 mm; females = 826.5 mm) were generally larger than Quinsam River fish (males = 763.5 mm; females = 803.8 mm) although the 95% confidence intervals of the mean lengths overlapped, suggesting that they were not significantly different.

The population escapement in each age class is shown in Tables 9 and 10 for Campbell and Quinsam rivers, respectively. The sex ratio in the Campbell was 692 males to 735 females (48.5%:51:5%; Table 9) and in the Quinsam was 698 males to 892 females (43.9%:56.1%; Table 10).

Biases in Aging Using Scales

The mean postorbital-hypural length of Campbell/Quinsam males with ages determined (774.5 mm ± 68.3 SD, Table 11) was significantly lower than that of males with unreadable scales (811.6 mm ± 94.0 SD; t=2.13, df=314, p<0.05, two-tailed). However, there was no significant difference between the mean lengths of females with ages determined (811.8 mm ± 46.6 SD) and females with unreadable scales (801.1 mm ± 65.5 SD; t=0.72, df=318, p>0.05, two-tailed).

Table 5. Campbell and Quinsam rivers chinook salmon Petersen estimates and enumeration data, 1985.

| Location and item | Male | Female | Adults unknown sex | Jack | Total |
|---|---|---|---|---|---|
| Campbell River | | | | | |
| Tagged | 102 | 77 | 0 | 21 | 200 |
| Dead recovery | 332 | 362 | 0 | 18 | 712 |
| Tag recovery | 54 | 38 | 0 | 6 | 98 |
| Tagged strays from Quinsam River | 0 | 0 | 0 | 0 | 0 |
| Tagged available for Petersen estimate[a] | 102 | 78 | 0 | 24 | 204 |
| Petersen estimate, sexes separate[a] | 624 | 735 | 0 | 68 | 1,427 |
| Quinsam River | | | | | |
| Tagged | 84 | 103 | 0 | 13 | 200 |
| Dead recovery | 434 | 512 | 13 | 29 | 988 |
| Tag recovery | 53 | 56 | 1 | 6 | 116 |
| Tagged strays from Campbell River | 0 | 1 | 0 | 1 | 2 |
| Tagged available for Petersen estimate[a] | 84 | 102 | 0 | 10 | 196 |
| Petersen estimate, sexes separate[a] | 651 | 892 | 0 | 47 | 1,590 |

[a] See methods section for method of calculation.

Table 6. Summary of Petersen estimates of chinook salmon escapement to Campbell and Quinsam rivers, 1985.

| River and sex | Petersen estimate | 95% CL[a] | |
|---|---|---|---|
| | | Lower | Upper |
| Campbell River | | | |
| Male | 624 | 512 | 736 |
| Female | 735 | 573 | 897 |
| Jack | 68 | 28 | 108 |
| Total | 1,427 | 1,226 | 1,628 |
| Quinsam River | | | |
| Male | 651 | 555 | 747 |
| Female | 892 | 747 | 1,037 |
| Jack | 47 | 27 | 67 |
| Total | 1,590 | 1,415 | 1,765 |
| Total | | | |
| Male | 1,275 | 1,128 | 1,422 |
| Female | 1,627 | 1,410 | 1,844 |
| Jack | 115 | 70 | 160 |
| Total | 3,017 | 2,751 | 3,283 |

[a] See methods section for method of calculation.

Table 7. Age composition of Campbell River chinook salmon, 1985. (Includes dead recovery sampling of marked and unmarked carcasses).

| Age | Sample size age determined | | | | Percent | Postorbital-hypural length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marked | | Unmarked | Total[b] | | N | Mean | SE | 95% CL | |
| | N | Adjusted N[a] | | | | | | | Lower | Upper |
| **Males** | | | | | | | | | | |
| $3_1$ | 1 | 0.7 | 3 | 3.7 | 1.5 | 4 | 556.2 | 2.5 | 545.4 | 567.0 |
| $4_1$ | 33 | 22.8 | 132 | 154.8 | 63.3 | 165 | 763.4 | 5.2 | 633.8 | 893.0 |
| $5_1$ | 6 | 4.2 | 76 | 80.2 | 32.8 | 82 | 859.8 | 6.3 | 750.8 | 968.9 |
| $6_1$ | 1 | 0.7 | 5 | 5.7 | 2.3 | 6 | 855.8 | 12.9 | 789.3 | 922.3 |
| Total aged | 41 | 28.4 | 216 | 244.4 | 100.0 | 257 | 793.1 | 3.9 | 671.9 | 914.3 |
| No Age | 4 | 2.8 | 32 | 34.8 | | | | | | |
| Total | 45[c] | 31.1 | 248 | 279.1 | | | | | | |
| **Females** | | | | | | | | | | |
| $4_1$ | 11 | 10.0 | 65 | 75.0 | 26.3 | 76 | 776.9 | 5.5 | 681.0 | 872.7 |
| $5_1$ | 14 | 12.7 | 178 | 190.7 | 66.8 | 191 | 838.5 | 3.3 | 750.0 | 927.0 |
| $6_1$ | 2 | 1.8 | 17 | 18.8 | 6.6 | 19 | 900.3 | 9.0 | 820.7 | 979.8 |
| $7_1$ | 0 | 0.0 | 1 | 1.0 | 0.4 | 1 | | | | |
| Total aged | 27 | 24.5 | 261 | 285.5 | 100.0 | 287 | 826.5 | 2.7 | 736.7 | 916.3 |
| No Age | 7 | 6.4 | 23 | 29.4 | | | | | | |
| Total | 34 | 30.9 | 284 | 314.9 | | | | | | |

[a] Adjusted to correct for intensive sampling of adipose-clipped rocoveries (factor for marked males = (46 marked/350 dead recovered) x (216/41) = 0.69; females = (34/362) x (261/27) = 0.91). Appendix 7 gives the total marked (i.e. adipose-clipped) recoveries and the total dead (marked and unmarked) recovery for each sex; male number includes jacks.

[b] Total = Adjusted marked + unmarked.

[c] One male included in Appendix 7 was not included here.

Table 8. Age composition of Quinsam River chinook salmon, 1985. (Includes dead recovery sampling of marked and unmarked carcasses).

| Age | Sample size age determined | | | | Percent | Postorbital-hypural length (mm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marked | | Unmarked | total[b] | | N | Mean | SE | 95% CL | |
| | N | Adjusted N[a] | | | | | | | Lower | Upper |
| **Males** | | | | | | | | | | |
| $3_1$ | 13 | 2.5 | 4 | 6.5 | 6.6 | 17 | 597.9 | 8.7 | 525.1 | 670.8 |
| $4_1$ | 101 | 19.2 | 35 | 54.2 | 54.7 | 134 | 758.8 | 5.1 | 643.9 | 873.7 |
| $4_1$ | 0 | 0.0 | 1 | 1.0 | 1.0 | 1 | 655.0 | | | |
| $5_1$ | 7 | 1.3 | 34 | 35.3 | 35.7 | 41 | 839.0 | 8.6 | 734.3 | 943.7 |
| $6_1$ | 0 | 0.0 | 1 | 1.0 | 1.0 | 1 | 999.0 | | | |
| $7_1$ | 0 | 0.0 | 1 | 1.0 | 1.0 | 1 | 990.0 | | | |
| Total aged | 121 | 23.0 | 76 | 99.0 | 100.0 | 195 | 763.5 | 4.0 | 654.7 | 872.3 |
| No age | 9 | 1.7 | 10 | 11.7 | | | | | | |
| Total | 130 | 24.7 | 86 | 110.7 | | | | | | |
| **Females** | | | | | | | | | | |
| $3_1$ | 1 | 0.3 | 1 | 1.3 | 1.0 | 2 | 752.5 | 0.0 | 752.5 | 752.5 |
| $4_1$ | 47 | 12.2 | 36 | 48.2 | 38.2 | 83 | 763.3 | 4.4 | 685.2 | 841.3 |
| $5_1$ | 31 | 8.1 | 57 | 65.1 | 51.6 | 87 | 836.9 | 5.5 | 739.8 | 933.3 |
| $5_1$ | 0 | 0.0 | 1 | 1.0 | 0.8 | 1 | 775.0 | | | |
| $6_1$ | 2 | 0.5 | 10 | 10.5 | 8.3 | 12 | 854.7 | 15.3 | 743.8 | 965.6 |
| Total aged | 81 | 21.1 | 105 | 126.1 | 100.0 | 185 | 803.8 | 3.4 | 714.5 | 893.0 |
| No age | 12 | 3.1 | 3 | 6.1 | | | | | | |
| Total | 93 | 24.2 | 108 | 132.2 | | | | | | |

[a] Adjusted to correct for intensive sampling of adipose-clipped recoveries (factor for marked males = (138.5 marked/469.5 dead recovered) x (76/121) = 0.19; females = (102.5/518.5) x (105/81) = 0.26). Appendix 8 gives the total marked (i.e. adipose-clipped) recoveries and the total dead (marked and unmarked) recovery for each sex; male number includes jacks; half of the marked and total dead recoveries of unknown sex were added to each sex.

[b] Total = Adjusted marked + unmarked.

Table 9. Petersen estimates of chinook salmon escapement to Campbell River allocated by age composition, 1985.

| Age | Males | | Females | |
|---|---|---|---|---|
| | Number | Percent[a] | Number | Percent |
| $3_1$ | 10 | 1.5 | 0 | 0.0 |
| $4_1$ | 438 | 63.3 | 193 | 26.3 |
| $5_1$ | 227 | 32.8 | 491 | 66.8 |
| $5_1$ | 16 | 2.3 | 49 | 6.6 |
| $7_1$ | 0 | 0.0 | 3 | 0.4 |
| Total | 692[b] | 100.0 | 735 | 100.0 |

[a] From Table 7.
[b] From Table 6; male number includes jacks.

Table 10. Petersen estimates of chinook salmon escapement to Campbell River allocated by age composition, 1985.

| Age | Males | | Females | |
|---|---|---|---|---|
| | Number | Percent[a] | Number | Percent |
| $3_1$ | 46 | 6.6 | 9 | 1.0 |
| $4_1$ | 382 | 54.7 | 341 | 38.0 |
| $4_1$ | 7 | 1.0 | 0 | 0.0 |
| $5_1$ | 249 | 35.7 | 460 | 51.6 |
| $5_1$ | 0 | 0.0 | 7 | 0.8 |
| $6_1$ | 7 | 1.0 | 74 | 8.3 |
| $7_1$ | 7 | 1.0 | 0 | 0.0 |
| Total | 698[b] | 100.0 | 892 | 100.0 |

[a] From Table 8.
[b] From Table 6; male number includes jacks.

Table 11. Age-length distribution of Quinsam/Campbell chinook salmon, 1985. (Dead recovery sample including marked and unmarked fish.)

| Length class (mm)[a] | Age | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | Total | Age unknown |
| **Males** | | | | | | | |
| 450-499 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 500-549 | 1 | 1 | 0 | 0 | 0 | 2 | 0 |
| 550-599 | 9 | 1 | 0 | 0 | 0 | 10 | 0 |
| 600-649 | 8 | 9 | 0 | 0 | 0 | 17 | 4 |
| 650-699 | 1 | 21 | 0 | 0 | 0 | 22 | 0 |
| 700-749 | 0 | 40 | 3 | 1 | 0 | 44 | 3 |
| 750-799 | 0 | 55 | 26 | 0 | 0 | 81 | 5 |
| 800-849 | 0 | 47 | 18 | 0 | 0 | 65 | 7 |
| 850-899 | 0 | 5 | 22 | 0 | 0 | 27 | 8 |
| 900-949 | 0 | 1 | 9 | 0 | 0 | 10 | 3 |
| 950-999 | 0 | 0 | 2 | 2 | 2 | 6 | 1 |
| Mean length | 590.3 | 761.4 | 840.1 | 899.3 | 990.0 | 774.5 | 811.6 |
| SD | 46.5 | 61.0 | 97.8 | 141.0 | 0.0 | 68.3 | 94.0 |
| Total | 20 | 180 | 80 | 3 | 2 | 285 | 31 |
| **Females** | | | | | | | |
| 650-699 | 2 | 7 | 0 | 0 | 0 | 9 | 1 |
| 700-749 | 0 | 34 | 6 | 0 | 0 | 40 | 4 |
| 750-799 | 0 | 57 | 36 | 5 | 0 | 98 | 6 |
| 800-849 | 1 | 18 | 48 | 5 | 0 | 72 | 6 |
| 850-899 | 0 | 1 | 56 | 9 | 0 | 66 | 2 |
| 900-949 | 0 | 0 | 10 | 3 | 0 | 13 | 0 |
| 950-999 | 0 | 0 | 0 | 2 | 0 | 2 | 1 |
| Mean length | 736.3 | 767.0 | 839.0 | 862.8 | - | 811.8 | 801.1 |
| SD | 60.8 | 40.3 | 49.4 | 54.1 | - | 46.6 | 65.5 |
| Total | 3 | 117 | 156 | 24 | 0 | 300 | 20 |

[a] Postorbital-hypural length.

CODED WIRE TAGGING AND RECOVERY

Coded wire tagged juvenile chinook released into the Campbell and Quinsam rivers from the 1979 to 1982 brood years were captured in the dead recovery programs in 1985.

The results of coded wire tag returns are presented below for the Campbell and Quinsam rivers. Information includes the following:

1) the raw data and mark rates for the calculations (Table 12);

2) the total estimates of adipose clips (Table 12);

3) the total estimated adipose clips partitioned between tag codes, and the hatchery contribution to the escapement for each tag code (Tables 13 and 14); and

4) the estimated hatchery contribution to the escapement by age class (Table 15).

There were 80 adipose clipped chinooks recovered in the Campbell River dead pitch and 244 in the Quinsam River dead pitch (Table 12). The adipose clip mark rate in the Quinsam was significantly higher than the mark rate in the Campbell (Campbell mark rate = 11.2%; Quinsam mark rate = 24.7%; contingency $\chi^2$=37.93, df=1, $p<0.001$). The mark rate of Area 1B in the Campbell, downstream of the confluence with the Quinsam (Fig. 1), was significantly greater than the mark rate of Area 1A upstream of the confluence (Area 1A mark rate = 6.7%; Area 2B mark rate = 12.2%; contingency $\chi^2$=6.68, df=1, $p<0.01$). There was no significant difference in the mark rates of the three recovery areas within the Quinsam (Area 2B mark rate = 21.4%; Area 2C mark rate = 26.9%; Area 2D mark rate = 22.2%; contingency $\chi^2$ =3.11, df=2, $p>0.05$). Adipose mark rates in different river areas were derived from Appendices 7 and 8.

The total estimated adipose clips to Campbell and Quinsam rivers were 160 and 393, respectively (Table 12).

Results from the decoding of CWTs from the Campbell and Quinsam rivers are shown in Tables 13 and 14. One CWT recovered in Campbell River had a Robertson Creek release code and was excluded from the analysis. Sixty-eight CWTs from the 78 heads sampled from adipose clipped fish in Campbell River were decoded; there were 10 heads with lost pins or no pins (Table 13). In Quinsam River, 214 CWTs from 237 heads sampled from adipose clipped fish were decoded; there were 23 heads with lost pins or no pins (Table 14). No heads were collected from adipose clipped jacks for CWT decoding, therefore there were no two year old males in the CWT analysis.

The allocations of the total escapement of adipose clips to tag codes recovered in each river are shown in Tables 13 and 14. The estimated hatchery contributions to escapement to the Campbell River were 269 males (38.9% of the escapement) and 370 females (50.3%; Table 15). Estimated hatchery contributions to the Quinsam escapements were 504 males (72.2% of the escapement) and 716 females (80.3%, Table 15). The hatchery contribution to the total escapement by age class is presented in Table 15.

Table 12. Estimates of the total escapement of adipose clips to the Campbell and Quinsam rivers, 1985.

| Location and sex | Sample size[a] A | Adipose clips observed B | Mark rate (%) C=(B/A)x100 | Petersen estimate of population size[b] D | Percentage of population sampled E=(A/D)x100 | Total estimated adipose clips F=(B/A)xD |
|---|---|---|---|---|---|---|
| Campbell River | | | | | | |
| Male | 332 | 45 | 13.6 | 624 | 53.2 | 85 |
| Female | 362 | 33 | 9.1 | 735 | 49.3 | 67 |
| Jack | 18 | 2 | 11.1 | 68 | 26.5 | 8 |
| Total | 712 | 80 | 11.2 | 1,427 | 49.9 | 160 |
| Quinsam River | | | | | | |
| Male | 434 | 131 | 30.2 | 651 | 67.7 | 197 |
| Female | 512 | 93 | 18.2 | 892 | 58.1 | 162 |
| Unknown sex adults[c] | 13 | 13 | - | - | - | - |
| Jack | 29 | 7[d] | 24.1 | 47 | 61.7 | 11 |
| Total | 988 | 244 | 24.7 | 1,590 | 62.1 | 393 |

[a] Dead recovery sample; see Table 5.
[b] From Table 6.
[c] Allocated equally to adult males and females in calculations.
[d] No heads taken for coded wire tag decoding.

Table 13. Estimates of total escapement of coded wire tagged chinook salmon to the Campbell River by tag code, 1985. (Dead recovery sample.)

| Brood year | Tag code | Observed adipose clips[b] | | Estimated adipose clips[c] | | Release numbers[a] | | Estimated hatchery contribution[d] | |
|---|---|---|---|---|---|---|---|---|---|
| | | Males | Females | Males | Females | Marked | Unmarked | Males | Females |
| | | A | B | C | D | E | F | G | H |
| 1982 | 082047 | 1 | 0 | 2 | 0 | 9,846 | 197 | 2 | 0 |
| 1981 | 022303 | 8 | 3 | 17 | 7 | 49,802 | 130,371 | 61 | 27 |
| | 022304 | 4 | 1 | 8 | 2 | 49,953 | 208,280 | 43 | 13 |
| | 082120 | 1 | 0 | 2 | 0 | 9,215 | 212 | 2 | 0 |
| | 082123 | 1 | 0 | 2 | 0 | 10,070 | 178 | 2 | 0 |
| | 082127 | 1 | 1 | 2 | 2 | 9,622 | 675 | 2 | 3 |
| | 082128 | 3 | 0 | 6 | 0 | 9,434 | 708 | 7 | 0 |
| | 082129 | 3 | 0 | 6 | 0 | 9,590 | 581 | 7 | 0 |
| | 082133 | 2 | 1 | 4 | 2 | 9,776 | 213 | 4 | 3 |
| | 082134 | 1 | 0 | 2 | 0 | 10,205 | 100 | 2 | 0 |
| | 082136 | 1 | 0 | 2 | 0 | 10,169 | 0 | 2 | 0 |
| | 082139 | 0 | 1 | 0 | 2 | 9,400 | 559 | 0 | 3 |
| | 082140 | 0 | 1 | 0 | 2 | 10,022 | 207 | 0 | 3 |
| | 082141 | 2 | 0 | 4 | 0 | 10,417 | 181 | 4 | 0 |
| | 082142 | 0 | 1 | 0 | 2 | 9,739 | 229 | 0 | 3 |
| | 082143 | 2 | 0 | 4 | 0 | 10,602 | 0 | 4 | 0 |
| | 082144 | 1 | 0 | 2 | 0 | 10,119 | 0 | 2 | 0 |
| | 082145 | 1 | 1 | 2 | 2 | 10,059 | 90 | 2 | 3 |
| | 082149 | 1 | 0 | 2 | 0 | 9,578 | 171 | 2 | 0 |
| | 082150 | 1 | 0 | 2 | 0 | 6,859 | 129 | 2 | 0 |
| | 082153 | 0 | 1 | 0 | 3 | 9,206 | 0 | 0 | 2 |
| 1980 | 021657 | 2 | 8 | 4 | 20 | 52,900 | 358,985 | 33 | 155 |
| | 021943 | 4 | 2 | 8 | 5 | 51,220 | 330,509 | 63 | 37 |
| | 021950 | 0 | 4 | 0 | 10 | 52,001 | 291,163 | 0 | 66 |
| 1979 | 021757 | 0 | 1 | 0 | 2 | 51,025 | 461,638 | 0 | 25 |
| | 021758 | 1 | 1 | 2 | 2 | 51,819 | 516,951 | 23 | 27 |
| Subtotal | | 41 | 27 | 85[d] | 67[d] | | | 269 | 370 |
| No pin | | 3 | 4 | | | | | | |
| Lost pin | | 1 | 2 | | | | | | |
| Total | | 45 | 33 | | | | | | |

[a] $C$ = Total estimated male adipose clips (Table 12) $\times \frac{A}{41 \text{ decoded tags}}$

[b] Johnson and Longwill (1988).

[c] $G = C \frac{(E + F)}{E}$ ; $H = D \frac{(E + F)}{E}$

[d] From Table 12.

Table 14. Estimates of total escapement of coded wire tags to the Quinsam River by tag code, 1985. (Dead recovery sample.)

| Brood year | Tag code | Observed adipose clips | | | Estimated adipose clips [a] | | Release numbers [b] | | Hatchery contribution [c] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | Female | Unknown sex [d] | Male | Female | Marked | Unmarked | Male | Female |
| | | A | B | C | D | E | F | G | H | I |
| 1982 | 022518 | 2 | 0 | 0 | 3 | 0 | 36,234 | 268,167 | 26 | 0 |
| | 022519 | 1 | 0 | 0 | 2 | 0 | 35,375 | 247,913 | 12 | 0 |
| | 082050 | 1 | 0 | 0 | 2 | 0 | 9,803 | 196 | 2 | 0 |
| | 082052 | 1 | 0 | 0 | 2 | 0 | 10,221 | 205 | 2 | 0 |
| | 082053 | 1 | 0 | 0 | 2 | 0 | 9,794 | 196 | 2 | 0 |
| | 082054 | 2 | 0 | 0 | 3 | 0 | 9,812 | 196 | 3 | 0 |
| | 082061 | 1 | 0 | 0 | 2 | 0 | 9,831 | 167 | 2 | 0 |
| | 082063 | 1 | 0 | 0 | 2 | 0 | 10,160 | 173 | 2 | 0 |
| | 082101 | 0 | 1 | 0 | 0 | 2 | 9,915 | 112 | 0 | 2 |
| | 082154 | 1 | 0 | 0 | 2 | 0 | 10,021 | 245 | 2 | 0 |
| | 082210 | 1 | 0 | 0 | 2 | 0 | 11,413 | 233 | 2 | 0 |
| | 082211 | 1 | 0 | 0 | 2 | 0 | 11,666 | 239 | 2 | 0 |
| 1981 | 022303 | 19 | 15 | 3 | 32 | 31 | 49,802 | 130,371 | 115 | 111 |
| | 022304 | 13 | 4 | 1 | 21 | 9 | 49,953 | 208,280 | 108 | 43 |
| | 082119 | 2 | 0 | 0 | 3 | 0 | 6,740 | 470 | 3 | 0 |
| | 082121 | 1 | 0 | 0 | 2 | 0 | 8,782 | 220 | 2 | 0 |
| | 082122 | 2 | 0 | 0 | 3 | 0 | 9,761 | 256 | 3 | 0 |
| | 082123 | 0 | 2 | 0 | 0 | 4 | 10,070 | 178 | 0 | 4 |
| | 082124 | 1 | 0 | 0 | 2 | 0 | 10,108 | 164 | 2 | 0 |
| | 082125 | 4 | 0 | 0 | 6 | 0 | 9,539 | 867 | 7 | 0 |
| | 082126 | 4 | 0 | 0 | 6 | 0 | 9,754 | 667 | 7 | 0 |
| | 082127 | 2 | 0 | 0 | 3 | 0 | 8,622 | 675 | 3 | 0 |
| | 082128 | 2 | 2 | 0 | 3 | 4 | 9,434 | 708 | 3 | 4 |
| | 082129 | 3 | 0 | 0 | 5 | 0 | 9,590 | 581 | 5 | 0 |
| | 082130 | 2 | 1 | 0 | 3 | 2 | 9,072 | 865 | 3 | 2 |
| | 082131 | 1 | 2 | 0 | 2 | 4 | 10,184 | 186 | 2 | 4 |
| | 082132 | 1 | 2 | 0 | 2 | 4 | 10,302 | 160 | 2 | 4 |
| | 082133 | 2 | 1 | 0 | 3 | 2 | 9,776 | 213 | 3 | 2 |
| | 082134 | 2 | 3 | 0 | 3 | 6 | 10,205 | 100 | 3 | 6 |
| | 082135 | 3 | 2 | 0 | 5 | 4 | 10,394 | 106 | 5 | 4 |
| | 082136 | 4 | 1 | 0 | 6 | 2 | 10,169 | 0 | 6 | 2 |
| | 082137 | 3 | 0 | 0 | 5 | 0 | 9,478 | 653 | 5 | 0 |
| | 082138 | 5 | 0 | 0 | 8 | 0 | 9,763 | 610 | 8 | 0 |
| | 082139 | 1 | 0 | 0 | 2 | 0 | 9,400 | 559 | 2 | 0 |
| | 082140 | 1 | 1 | 0 | 2 | 2 | 10,022 | 207 | 2 | 2 |
| | 082141 | 1 | 1 | 0 | 2 | 2 | 10,417 | 181 | 2 | 2 |
| | 082142 | 2 | 0 | 1 | 4 | 1 | 9,739 | 229 | 4 | 1 |
| | 082143 | 3 | 1 | 1 | 5 | 3 | 10,602 | 0 | 5 | 3 |
| | 082144 | 1 | 2 | 0 | 2 | 4 | 10,119 | 0 | 2 | 4 |
| | 082145 | 3 | 1 | 0 | 5 | 2 | 10 059 | 90 | 5 | 2 |

continued

Table 14 continued

| Brood year | Tag code | Observed adipose clips | | | Estimated adipose clips[a] | | Release Numbers[b] | | Hatchery contribution[c] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | Female | Unknown sexd | Male | Female | Marked | Unmarked | Male | Female |
| | | A | B | C | D | E | F | G | H | I |
| 1981 | 082146 | 2 | 1 | 0 | 3 | 2 | 9,074 | 734 | 3 | 2 |
| | 082147 | 5 | 0 | 0 | 8 | 0 | 9,249 | 881 | 8 | 0 |
| | 082149 | 3 | 0 | 0 | 5 | 0 | 9,578 | 171 | 5 | 0 |
| | 082150 | 1 | 2 | 1 | 2 | 5 | 6,859 | 129 | 2 | 5 |
| | 082152 | 1 | 1 | 0 | 2 | 2 | 9,704 | 0 | 2 | 2 |
| | 082153 | 1 | 2 | 0 | 2 | 4 | 9,206 | 0 | 2 | 4 |
| 1980 | 021657 | 2 | 11 | 3 | 5 | 23 | 52,900 | 358,985 | 42 | 181 |
| | 021943 | 3 | 16 | 0 | 5 | 30 | 51,220 | 330,509 | 35 | 222 |
| | 021950 | 2 | 4 | 2 | 5 | 9 | 52,001 | 291,163 | 31 | 61 |
| 1979 | 021757 | 0 | 2 | 0 | 0 | 4 | 51,025 | 461,638 | 0 | 37 |
| Subtotal | | 121 | 81 | 12 | 197[e] | 162[e] | | | 504 | 716 |
| No pin | | 8 | 10 | 0 | | | | | | |
| Lost pin | | 2 | 2 | 1 | | | | | | |
| Total | | 131 | 93 | 13 | | | | | | |

[a] D = Total estimated male adipose clips (Table 12) $\times \frac{A + (0.5\ C)}{121 + (12/2)\ \text{decoded tags}}$

[b] Johnson and Longwill (1988).

[c] $H = D \frac{(F + G)}{F}$ ; $I = E \frac{(F + G)}{F}$

[d] Allocated equally between males and females in calculations.

[e] From Table 12.

Table 15. Estimated hatchery contribution to the 1985 Campbell and Quinsam rivers chinook salmon escapement.

| Age | Estimated escapement[a] A | Hatchery contribution[b] B | % Hatchery contribution C=(B/A)x100 |
|---|---|---|---|
| **Campbell River males** | | | |
| 3 | 10 | 2 | 20.0 |
| 4 | 438 | 148 | 33.8 |
| 5 | 227 | 96 | 42.3 |
| 6 | 16 | 23 | 100.0[c] |
| Total | 692 | 269 | 38.9 |
| **Campbell River females** | | | |
| 4 | 193 | 60 | 31.1 |
| 5 | 491 | 258 | 52.5 |
| 6 | 49 | 52 | 100.0[c] |
| 7 | 3 | 0 | 0.0 |
| Total | 735 | 370 | 50.3 |
| **Quinsam River males** | | | |
| 3 | 46 | 57 | 100.0[c] |
| 4 | 389 | 339 | 87.1 |
| 5 | 249 | 108 | 43.4 |
| 6 | 7 | 0 | 0.0 |
| 7 | 7 | 0 | 0.0 |
| Total | 698 | 504 | 72.2 |
| **Quinsam River females** | | | |
| 3 | 9 | 2 | 22.2 |
| 4 | 341 | 213 | 62.5 |
| 5 | 467 | 464 | 100.0 |
| 6 | 74 | 37 | 50.0 |
| Total | 892 | 716 | 80.3 |

[a] From Tables 9 and 10; male number includes jacks.

[b] From Tables 13 and 14.

[c] Hatchery contribution was calculated to be greater than the estimated escapement, therefore the hatchery contribution was assumed to be 100% of the escapement.

## DISCUSSION AND CONCLUSIONS

### POPULATION ESTIMATION

The Petersen escapement estimates of chinook salmon to the Campbell and Quinsam rivers were 1,427 and 1,590 spawners, respectively (Table 6). These data were calculated by sum of Petersen estimates for separate sexes.

Several potentially important sources of bias in Petersen estimates caused by factors which affect sexes differently were circumvented by stratifying the populations of each river by sex. In this study, there were factors that affected sexes differentially, as indicated by differences in the sex ratios obtained in hatchery seining for broodstock, dead recovery, and Petersen estimates. The sex ratio in the hatchery seining was 51.8% males and 48.2% females (sample size = 1,592) (J. Van Tine, pers. comm., 1988) and in the Campbell dead recovery was 49.2% males and 50.8% females (sample size = 712) and Quinsam dead recovery 47.5% males and 52.5% females (sample size = 988), whereas the sex ratios determined in Petersen estimates were 48.5% males and 51.5% females in the Campbell (total population = 1,427) and 43.9% males and 56.1% females in the Quinsam (total population = 1,590). The large number of males captured in hatchery seining might be attributable to the recapture of released males (up to 25% of the catch of males was released) and the selection of males by seines due to their greater tangling rate caused by numerous sharp protrusions, particuly in the head area (Wilson and Andrew 1987). The smaller proportion of males recovered in the dead pitch may have been due to a greater washout rate of males than females, as female salmon normally hold over their redds after spawning and move into shallow quiet water as they weaken, where they are easily recovered, whereas males make a lesser attempt to hold their position and are washed out by the water current. Higher proportions of females than males have been observed in spawning ground dead pitches for sockeye (Petersen 1954), pinks (Ward 1959), and coho (Eames and Himo 1981 and Eames et al. 1981), and this appears to be the case for chinook (Shardlow et al. 1986). In future studies, population estimates conducted on the Campbell and Quinsam rivers should be calculated by stratifying the population by sex.

Potentially important sources of bias in Petersen estimates were also circumvented by stratifying the estimate by river. However, there was no significant difference between the tag recovery rates in Campbell and Quinsam rivers (sexes pooled; contingency $\chi^2=1.51$, df=1, $p>0.05$).

A high degree of straying by live-tagged fish was circumvented by the use of tagged carcasses. However, one factor which could have produced a serious bias in the Petersen estimate is the incomplete mixing of tagged carcasses with the rest of the carcass population, particularly in deep pools, where many carcasses may have been immobilized. In addition, errors in the raw data may have caused an over- or underestimation of the escapements. For example, one female and one jack carcass were recorded as straying from the Campbell upstream to the Quinsam (Table 5). Unless carcasses were transported by predators, these data were recorded incorrectly.

Petersen estimates may be biased if either tagging or recovery effort is not allocated proportionally to where spawners are located. The differential numbers recovered in river areas (83.1% of the Campbell dead recovery was in Area 1B and 65% of the Quinsam dead recovery was in Areas 2B and 2C) indicates that spawners were not evenly distributed in either river. The release of tagged carcasses in each river according to the distribution of spawners was determined in a preliminary carcass survey which occured before carcass tagged fish were released. To circumvent this potential bias, this procedure should be continued in future Petersen programs. In addition, recovery effort should be allocated equally to each area such that the number of dead recoveries is in proportion to the number of spawners.

In the Campbell, some of the fish recovered in the lower river area may have spawned in the upper reaches and the carcasses washed downstream as a result of normal stream flow and water being released from the generating station. In the Quinsam, the high number of spawners in the upper half of the river may have resulted in part from fish reluctant to enter the hatchery fishway spawning in the river adjacent to the fishway. Smaller and more consistent flows in the Quinsam relative to the Campbell, would tend not to wash carcasses downstream to the same extent as in the Campbell (mean annual discharge in Campbell from 1950 to 1970 was 96.0 $m^3s^{-1}$, in Quinsam from 1957 to 1986 was 9.0 $m^3s^{-1}$. The mean annual discharge in the Quinsam in 1985 (mean=4.58 $m^3s^{-1}$; Fig. 2) was approximately half of the mean annual discharge of the river.

Recognition of tags may have been less than 100%. The rate of missed opercular punches on chinook salmon in the Harrison River was approximately 10% (K. Wilson, Biologist, Department of Fisheries and Oceans, 555 W. Hastings Street, Vancouver, B.C., V6B 5G3, pers. comm. 1987) and approximately 10% of a known group of spaghetti tags in the Somass River were undetected (Shardlow et al. 1986). We were not able to test for this source of bias in the present study, but in future studies, repitches of carcasses should be conducted to make adjustments for the proportion of missed tags.

A frequent source of bias in Petersen estimates of fish populations is tag loss (Ricker 1975). Electrical strap tagging appears to be particularly effective for chinook salmon, as indicated by the zero percent tag loss in the present study. This suggests that electrical strap tags should be used in future studies; however, such a conclusion may be premature based on only 50 tagged fish that could be assessed for tag loss.

In future enumeration of the Campbell and Quinsam chinook salmon escapement, carcass tagging programs should be designed in a similar way to the 1985 study. Programs should include tag and recovery rates with equal effort in proportion to the number of spawners in each area, and Petersen estimates should be stratified by river and sex. Such procedures should result in estimates with reasonable levels of precision.

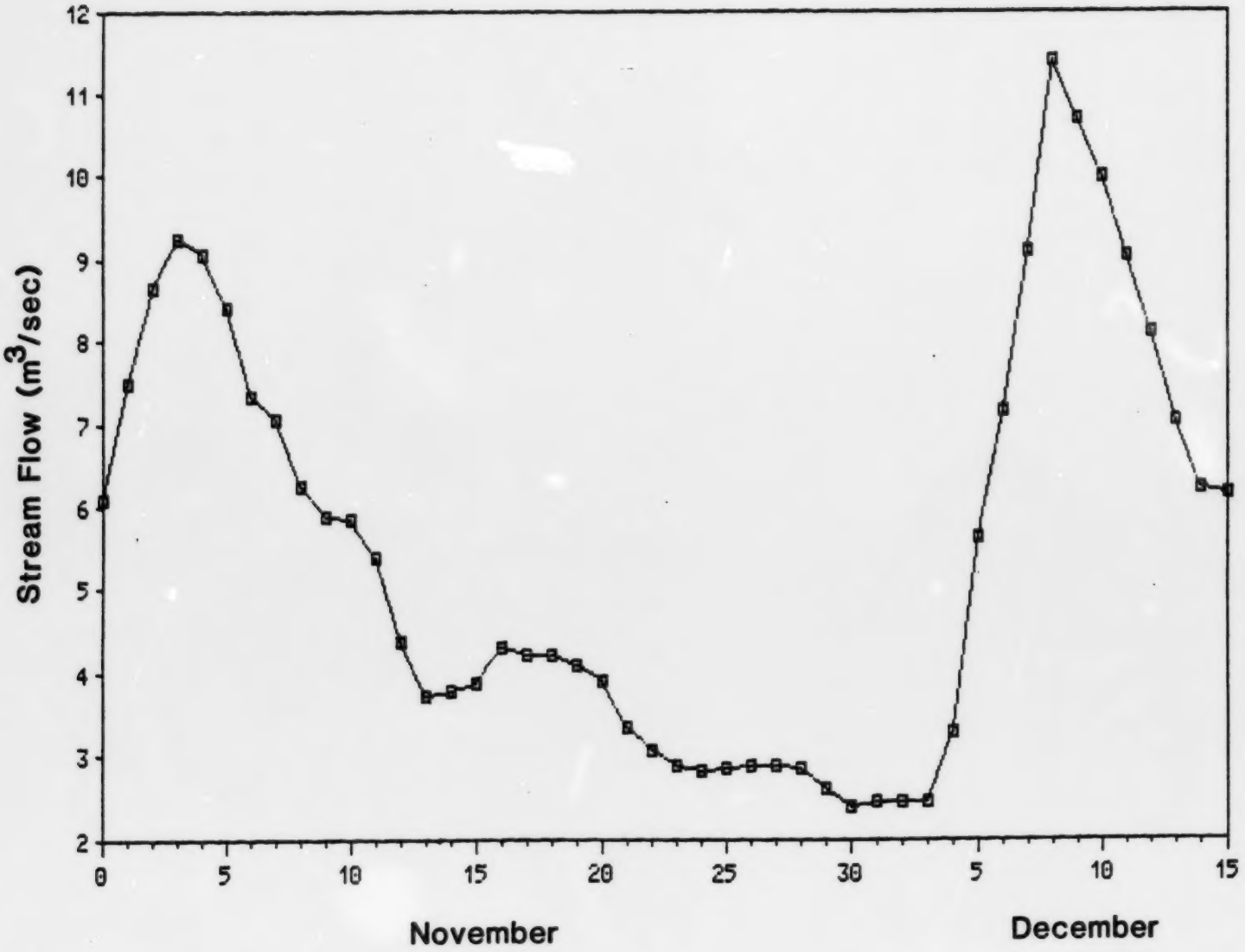


Figure 2. Stream flow of the Quinsam River, 1985. Data from Water Survey of Canada (Station 08HD005 Quinsam River near Campbell River); mean annual discharge from 1957 to 1986 = 9.0 $m^3 sec^{-1}$ and mean annual discharge in 1985 = 4.58 $m^3 sec^{-1}$).

## AGE, LENGTH AND SEX COMPOSITION

Age and length samples were collected in the dead recovery such that there was a random sampling of the unmarked population, and these data were pooled with data from intensive sampling of marked (adipose clipped) fish. Weighting of data from marked fish corrected for the greater intensity of sampling of marked fish.

Age compositions may be biased if scale readability varies with size or age of fish. Testing for bias in scale readability with age was performed by comparing the mean length of fish with ages determined with that of unaged fish with unreadable scales. There was no significant difference among females ($t=0.72$, $df=318$, $p>0.05$), but the mean length of males with ages determined was significantly lower than that males with unreadable scales ($t=2.13$, $df=314$, $p<0.05$). Larger males are generally older and may have lost and regenerated a greater proportion of their scales, resulting in a greater number of unreadable scales.

In future studies, age and length analyses of Campbell and Quinsam chinook populations should be conducted separately because in the Campbell, there is a population of naturally-derived spawners composed of larger, older fish and a small proportion of jacks than hatchery-derived spawners (J. Van Tine, Manager, Quinsam Hatchery, Pers. Comm., 1988). There are few naturally-derived spawners in the Quinsam escapement, and among the hatchery-derived spawners, there is a relatively large proportion of jacks. Jacks frequently return to spawn in the vicinity of the hatchery or are collected at the hatchery rack.

The Campbell and Quinsam rivers chinook escapements are composed mainly of age $4_1$ and $5_1$ fish. The sex ratio of the Campbell River escapement was 48.5% males and 51.5% females, and that of the Quinsam escapement was 43.9% males and 56.1% females.

## CODED WIRE TAGGING AND RECOVERY

The large number of coded wire tag returns to the Campbell and Quinsam is due mainly to intensive marking of experimental groups by the Department of Fisheries and Oceans Research Branch, starting with the 1981 brood. From the experimental groups, only the 3 and 4 year old fish returned in 1985, resulting in a preponderance of marked males.

In this study, we used the adipose clip rate in the dead recovery to estimate the number of adipose clips in the escapement. The combined live sample from hatchery seining, the fence and the hatchery rack was not used to determine the mark rate for this study because in 1985, there was a higher proportion of marked jacks at the hatchery rack and fence than in the spawning population of Quinsam River (J. Van Tine, Manager, Quinsam Hatchery, pers. comm., 1988). The adipose clip rate in the combined live sample was 31.7%, which was higher than the dead recovery mark rates in both the Quinsam (24.4%) and the Campbell (11.2%). The best sample for a mark rate for future studies would be an unbiased live sample, which could be obtained in conjunction with hatchery broodstock collection. Hatchery broodstock collection should be designed to randomly sample the escapement in both rivers, and the sample should be used to determine a live sample mark rate.

The patchy distribution of adipose clipped fish may introduce a significant bias in the estimation of the escapement of adipose clipped fish and the hatchery contribution to escapement. The mark rate in the Campbell downstream of the confluence with the Quinsam was significantly greater than the mark rate upstream of the confluence (contingency $\chi^2$=6.68, df=1, p<0.01). However, there was no significant difference in the mark rates of the three recovery areas in the Quinsam (contingency $\chi^2$=3.11, df=2, p>0.05).

Although we have tried to address as many potential sources of bias as possible in the estimation of the escapement of CWTs described above, we have not explicitly included the following factors:

1) The low number of recoveries of adipose clips and decoded CWTs (less than 20 CWTs in some brood years) may make the precision of the estimates so low as to be of relatively little use in those brood years; and

2) The sample of heads obtained for the decoding of CWTs may not be a random sample from the population and might contain a bias due to size selectivity or other factors.

We have not formally estimated the level of precision of the estimates of escapement by adipose clipped fish and individual tag codes as potential sources of bias can render these misleading. An approximation of the level of precision can be obtained by examining the number of adipose clips/CWT recoveries on which a given estimate is based. There were 27 to 127 adipose clips enumerated for each sex. The 95% confidence limits for 27 recoveries (based on a Poisson frequency distribution) range from 18 to 40 fish; thus we could expect an estimate based on this number of recoveries to have 95% limits as narrow as ± 48%. For 127 recoveries the 95% limits would be as narrow as ± 17%. These estimates of precision are conservative because the expansion factors used to estimate the total number of adipose clips/marks in the escapement are also estimated with error. In future programs, sampling of adipose clipped fish should not be selective in any way, for example releasing large females but sampling small females for coded wire tags.

In Campbell River, the hatchery contributed 38.9% of the male escapement and 50.3% of the females escapement. In Quinsam River, the hatchery contributed 72.2% of the male and 80.3% of the female escapement. The higher proportion of chinook of hatchery origin in Quinsam River is almost certainly attributable to the release of artificially propagated fish from the Quinsam Hatchery.

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# APPENDICES

Appendix 1. Release of tagged chinook salmon carcasses in the Campbell River, 1985.

| Date | Release site[a] | Tag colour | Released | | | |
|---|---|---|---|---|---|---|
| | | | Males | Females | Jacks | Total |
| October 31 | Upper channel | Brown | 2 | 2 | 1 | 5 |
| | Lower channel | | 2 | 2 | 1 | 5 |
| | Above pumphouse | | 4 | 4 | 2 | 10 |
| | Logging bridge | | 10 | 4 | 1 | 15 |
| | Highway bridge | | 12 | 2 | 1 | 15 |
| | Total | | 30 | 14 | 6 | 50 |
| November 6 | Upper channel | Blue | 2 | 2 | 1 | 5 |
| | Lower channel | | 3 | 2 | 0 | 5 |
| | Above pumphouse | | 5 | 4 | 1 | 10 |
| | Logging bridge | | 9 | 5 | 1 | 15 |
| | Highway bridge | | 5 | 8 | 2 | 15 |
| | Total | | 24 | 21 | 5 | 50 |
| November 12 | Upper channel | Green | 2 | 2 | 1 | 5 |
| | Lower channel | | 3 | 1 | 1 | 5 |
| | Above pumphouse | | 4 | 5 | 1 | 10 |
| | Logging bridge | | 7 | 7 | 1 | 15 |
| | Highway bridge | | 4 | 6 | 5 | 15 |
| | Total | | 20 | 21 | 9 | 50 |
| November 15 | Upper channel | Black | 3 | 2 | 0 | 5 |
| | Lower channel | | 1 | 3 | 1 | 5 |
| | Above pumphouse | | 5 | 5 | 0 | 10 |
| | Logging bridge | | 10 | 5 | 0 | 15 |
| | Highway bridge | | 9 | 6 | 0 | 15 |
| | Total | | 28 | 21 | 1 | 50 |
| | Grand Total | | 102 | 77 | 21 | 200 |

[a]See Figure 1 for location of release sites.

Appendix 2. Release of tagged chinook salmon carcasses in the Quinsam River, 1985.

| Date | Release site[a] | Tag colour | Released | | | |
|---|---|---|---|---|---|---|
| | | | Males | Females | Jacks | Total |
| October 31 | Fence | Black/ | 5 | 4 | 1 | 10 |
| | Leaf trap | green | 4 | 5 | 1 | 10 |
| | Dyke | | 5 | 5 | 0 | 10 |
| | Cold Creek | | 4 | 3 | 1 | 8 |
| | Alder Run | | 3 | 3 | 1 | 7 |
| | Argonaut Br. | | 2 | 1 | 0 | 3 |
| | Campsite | | 0 | 1 | 1 | 2 |
| | Total | | 23 | 22 | 5 | 50 |
| November 6 | Fence | Black/ | 2 | 7 | 1 | 10 |
| | Leaf trap | brown | 3 | 6 | 1 | 10 |
| | Dyke | | 3 | 7 | 0 | 10 |
| | Cold Creek | | 4 | 4 | 0 | 8 |
| | Alder Run | | 3 | 4 | 0 | 7 |
| | Argonaut Br. | | 1 | 2 | 0 | 3 |
| | Campsite | | 1 | 1 | 0 | 2 |
| | Total | | 17 | 31 | 2 | 50 |
| November 12 | Fence | Black/ | 4 | 5 | 1 | 10 |
| | Leaf trap | blue | 5 | 5 | 0 | 10 |
| | Dyke | | 5 | 4 | 1 | 10 |
| | Cold Creek | | 2 | 6 | 0 | 8 |
| | Alder Run | | 3 | 3 | 1 | 7 |
| | Argonaut Br. | | 2 | 1 | 0 | 3 |
| | Campsite | | 0 | 2 | 0 | 2 |
| | Total | | 21 | 26 | 3 | 50 |
| November 15 | Fence | Double | 5 | 5 | 0 | 10 |
| | Leaf trap | black/grey | 5 | 5 | 0 | 10 |
| | Dyke | | 4 | 5 | 1 | 10 |
| | Cold Creek | | 3 | 4 | 1 | 8 |
| | Alder Run | | 3 | 3 | 1 | 7 |
| | Argonaut Br. | | 2 | 1 | 0 | 3 |
| | Campsite | | 1 | 1 | 0 | 2 |
| | Total | | 23 | 24 | 3 | 50 |
| | Grand total | | 84 | 103 | 13 | 200 |

[a] See Figure 1 for location of release sites.

Appendix 3. Dead recovery of chinook salmon in the Campbell River, 1985.

| Date | Total recovered | | | |
|---|---|---|---|---|
| | Males | Females | Jacks | Total |
| October 23 | 1 | 0 | 0 | 1 |
| October 28 | 12 | 5 | 0 | 17 |
| October 29 | 11 | 9 | 0 | 20 |
| October 31 | 34 | 25 | 1 | 60 |
| November 1 | 39 | 26 | 6 | 71 |
| November 4 | 44 | 39 | 2 | 85 |
| November 7 | 28 | 40 | 2 | 70 |
| November 8 | 42 | 41 | 2 | 85 |
| November 13 | 49 | 60 | 5 | 114 |
| November 14 | 2 | 12 | 0 | 14 |
| November 15 | 12 | 14 | 0 | 26 |
| November 18 | 18 | 25 | 0 | 43 |
| November 20 | 2 | 6 | 0 | 8 |
| November 21 | 9 | 10 | 0 | 19 |
| November 25 | 5 | 11 | 0 | 16 |
| November 29 | 5 | 13 | 0 | 18 |
| December 4 | 14 | 15 | 0 | 29 |
| December 5 | 0 | 2 | 0 | 2 |
| December 6 | 5 | 9 | 0 | 14 |
| Total | 332 | 362 | 18 | 712 |

Appendix 4. Dead recovery of chinook salmon in the Quinsam River, 1985.

| Date | Total recovered | | | | |
|---|---|---|---|---|---|
| | Males | Females | Jacks | Sex unknown | Total |
| October 30 | 12 | 26 | 0 | 0 | 38 |
| November 5 | 91 | 89 | 8 | 0 | 188 |
| November 6 | 41 | 65 | 2 | 0 | 108 |
| November 7 | 16 | 22 | 2 | 0 | 40 |
| November 11 | 62 | 78 | 5 | 0 | 145 |
| November 12 | 29 | 18 | 0 | 0 | 47 |
| November 14 | 14 | 31 | 3 | 13 | 61 |
| November 15 | 27 | 24 | 0 | 0 | 51 |
| November 19 | 28 | 41 | 2 | 0 | 71 |
| November 20 | 8 | 7 | 0 | 0 | 15 |
| November 22 | 43 | 48 | 1 | 0 | 92 |
| November 25 | 5 | 6 | 0 | 0 | 11 |
| November 26 | 9 | 9 | 1 | 0 | 19 |
| November 27 | 6 | 2 | 1 | 0 | 9 |
| December 2 | 20 | 20 | 2 | 0 | 42 |
| December 3 | 9 | 7 | 2 | 0 | 18 |
| December 5 | 0 | 2 | 0 | 0 | 2 |
| December 11 | 6 | 15 | 0 | 0 | 21 |
| December 12 | 8 | 2 | 0 | 0 | 10 |
| Total | 434 | 512 | 29 | 13 | 988 |

Appendix 5. Tag recovery in the Campbell River, 1985.

| Tag colour | Tags released | | | | Date recovered | Recovery area[a] | Tagged carcasses recovered | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Males | Females | Jacks | Total | | | Males | Females | Total adults | Jacks | Total |
| Brown | 30 | 14 | 6 | 50 | Nov 1 | 1B | 4 | 2 | 6 | 0 | 6 |
| | | | | | Nov 4 | 1B | 4 | 1 | 5 | 0 | 5 |
| Oct 31 release | | | | | Nov 4 | 1A | 0 | 3 | 3 | 1 | 4 |
| | | | | | Nov 7 | 1A | 1 | 0 | 1 | 2 | 3 |
| | | | | | Nov 7 | 1B | 3 | 2 | 5 | 0 | 5 |
| | | | | | Nov 8 | 1B | 0 | 1 | 1 | 0 | 1 |
| | | | | | Nov 13 | 1B | 1 | 0 | 1 | 0 | 1 |
| | | | | | Nov 15 | 1B | 1 | 0 | 1 | 0 | 1 |
| | | | | | Total | | 14 | 9 | 23 | 3 | 26 |
| Blue | 24 | 21 | 5 | 50 | Nov 7 | 1A | 4 | 3 | 7 | 1 | 8 |
| | | | | | Nov 7 | 1B | 6 | 2 | 8 | 0 | 8 |
| | | | | | Nov 8 | 1B | 1 | 1 | 2 | 1 | 3 |
| Nov 6 release | | | | | Nov 13 | 1A | 0 | 1 | 1 | 0 | 1 |
| | | | | | Nov 13 | 1B | 2 | 4 | 6 | 0 | 6 |
| | | | | | Nov 14 | 1B | 2 | 0 | 2 | 0 | 2 |
| | | | | | Nov 14 | 1A | 0 | 1 | 1 | 0 | 1 |
| | | | | | Nov 15 | 1B | 2 | 0 | 2 | 0 | 2 |
| | | | | | Nov 18 | 1B | 1 | 0 | 1 | 0 | 1 |
| | | | | | Dec 4 | 1B | 0 | 1 | 1 | 0 | 1 |
| | | | | | Total | | 18 | 13 | 31 | 2 | 33 |
| Green | 20 | 21 | 9 | 50 | Nov 13 | 1A | 0 | 0 | 0 | 1 | 1 |
| | | | | | Nov 13 | 1B | 1 | 2 | 3 | 0 | 3 |
| | | | | | Nov 14 | 1A | 1 | 1 | 2 | 0 | 2 |
| Nov 12 release | | | | | Nov 14 | 1B | 5 | 4 | 9 | 0 | 9 |
| | | | | | Nov 15 | 1B | 1 | 0 | 1 | 0 | 1 |
| | | | | | Nov 18 | 1B | 2 | 0 | 2 | 0 | 2 |
| | | | | | Nov 21 | 1B | 0 | 1 | 1 | 0 | 1 |
| | | | | | Nov 29 | 1B | 1 | 0 | 1 | 0 | 1 |
| | | | | | Dec 4 | 1A | 0 | 2 | 2 | 0 | 2 |
| | | | | | Total | | 11 | 10 | 21 | 1 | 22 |
| Black | 28 | 21 | 1 | 50 | Nov 18 | 1A | 1 | 2 | 3 | 0 | 3 |
| | | | | | Nov 18 | 1B | 2 | 1 | 3 | 0 | 3 |
| | | | | | Nov 21 | 1B | 2 | 1 | 3 | 0 | 3 |
| Nov 15 release | | | | | Nov 27 | 1A | 1 | 0 | 1 | 0 | 1 |
| | | | | | Nov 29 | 1B | 1 | 0 | 1 | 0 | 1 |
| | | | | | Nov 29 | 1A | 0 | 1 | 1 | 0 | 1 |
| | | | | | Dec 4 | 1A | 3 | 1 | 4 | 0 | 4 |
| | | | | | Dec 4 | 1B | 1 | 0 | 1 | 0 | 1 |
| | | | | | Total | | 11 | 6 | 17 | 0 | 17 |
| Total | 102 | 77 | 21 | 200 | | | 54 | 38 | 92 | 6 | 98 |

[a] See Figure 1 for area locations.

Appendix 6. Tag recovery in the Quinsam river, 1985.

| Tag colour | Tags released | | | | Date recovered | Recovery area[a] | Tagged carcasses recovered | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Males | Females | Unknown adults | Total adults | Jacks | Total |
| Black/green | 23 | 22 | 5 | 50 | Nov 5 | 2D | 1 | 2 | 0 | 3 | 0 | 3 |
| | | | | | Nov 5 | 2D | 1 | 0 | 0 | 1 | 0 | 1 |
| Oct 31 release | | | | | Nov 5 | 2B | 1 | 6 | 0 | 7 | 1 | 8 |
| | | | | | Nov 6 | 2C | 3 | 1 | 0 | 4 | 0 | 4 |
| | | | | | Nov 7 | 1B | 0 | 0 | 0 | 0 | 1 | 1 |
| | | | | | Nov 11 | 2C | 1 | 0 | 0 | 1 | 0 | 1 |
| | | | | | Nov 14 | 2B | 2 | 0 | 0 | 2 | 0 | 2 |
| | | | | | Nov 19 | 2C | 1 | 0 | 0 | 1 | 0 | 1 |
| | | | | | Nov 22 | 2C | 1 | 0 | 0 | 1 | 0 | 1 |
| | | | | | Nov 25 | 1B | 0 | 1 | 0 | 1 | 0 | 1 |
| | | | | | Dec 2 | 2C | 0 | 1 | 0 | 1 | 0 | 1 |
| | | | | | Total(incl. Campbell) | | 11 | 11 | 0 | 22 | 2 | 24 |
| Black/Brown | 17 | 31 | 2 | 50 | Nov 7 | 2C | 0 | 1 | 0 | 1 | 1 | 2 |
| | | | | | Nov 11 | 2C | 3 | 1 | 0 | 4 | 0 | 4 |
| Nov 6 release | | | | | Nov 11 | 2D | 1 | 0 | 0 | 1 | 0 | 1 |
| | | | | | Nov 11 | 2B | 3 | 1 | 0 | 4 | 0 | 4 |
| | | | | | Nov 14 | 2B | 1 | 2 | 0 | 3 | 0 | 3 |
| | | | | | Nov 14 | 2C | 0 | 2 | 0 | 2 | 1 | 3 |
| | | | | | Nov 19 | 2D | 1 | 1 | 0 | 2 | 0 | 2 |
| | | | | | Nov 19 | 2B | 0 | 1 | 0 | 1 | 0 | 1 |
| | | | | | Nov 22 | 2B | 0 | 1 | 0 | 1 | 0 | 1 |
| | | | | | Nov 22 | 2C | 0 | 1 | 0 | 1 | 0 | 1 |
| | | | | | Nov 24 | 2B | 0 | 3 | 0 | 3 | 0 | 3 |
| | | | | | Nov 26 | 2D | 0 | 1 | 0 | 1 | 0 | 1 |
| | | | | | Total | | 9 | 15 | 0 | 24 | 2 | 26 |
| Black/Blue | 21 | 26 | 3 | 50 | Nov 14 | 2B | 4 | 6 | 0 | 10 | 0 | 10 |
| | | | | | Nov 14 | 2C | 2 | 3 | 0 | 5 | 1 | 6 |
| Nov 12 release | | | | | Nov 19 | 2B | 1 | 0 | 0 | 1 | 0 | 1 |
| | | | | | Nov 19 | 2C | 1 | 1 | 0 | 2 | 0 | 2 |
| | | | | | Nov 19 | 2D | 1 | 0 | 0 | 1 | 0 | 1 |
| | | | | | Nov 22 | 2B | 0 | 1 | 0 | 1 | 0 | 1 |
| | | | | | Nov 22 | 2C | 0 | 2 | 0 | 2 | 0 | 2 |
| | | | | | Nov 24 | 2B | 4 | 4 | 0 | 8 | 0 | 8 |
| | | | | | Dec 11 | 2B&2C | 1 | 1 | 0 | 2 | 0 | 2 |
| | | | | | Dec 12 | 2B | 0 | 0 | 0 | 0 | 1 | 1 |
| | | | | | Total | | 14 | 18 | 0 | 32 | 2 | 34 |
| Black/Grey | 23 | 24 | 3 | 50 | Nov 19 | 2B | 5 | 6 | 0 | 11 | 0 | 11 |
| | | | | | Nov 19 | 2C | 2 | 0 | 0 | 2 | 0 | 2 |
| Nov 13 release | | | | | Nov 19 | 2D | 1 | 0 | 0 | 1 | 0 | 1 |
| | | | | | Nov 20 | 2D | 1 | 1 | 0 | 2 | 0 | 2 |
| | | | | | Nov 22 | 2B | 0 | 0 | 1 | 1 | 0 | 1 |
| | | | | | Nov 22 | 2C | 3 | 1 | 0 | 4 | 0 | 4 |
| | | | | | Nov 24 | 2B | 4 | 2 | 0 | 6 | 0 | 6 |
| | | | | | Nov 25 | 2B | 1 | 1 | 0 | 2 | 0 | 2 |
| | | | | | Dec 2 | 2C | 1 | 1 | 0 | 2 | 0 | 2 |
| | | | | | Dec 11 | 2C | 1 | 0 | 0 | 1 | 0 | 1 |
| | | | | | Total | | 19 | 12 | 1 | 32 | 0 | 32 |
| Total | 84 | 103 | 13 | 200 | | | 53 | 56 | 1 | 110 | 6 | 116 |

[a] See Figure 1 for area locations.

Appendix 7. Dead recovery and adipose clip recovery in the Campbell River, 1985.

| Date | Total recovered[a] | | | | Adipose clipped recovered[b] | | | |
|---|---|---|---|---|---|---|---|---|
| | M | F | J | Total | M | F | J | Total |
| Area 1A[c] | | | | | | | | |
| Oct 23 | | | | 0 | | | | 0 |
| Oct 28 | | | | 0 | | | | 0 |
| Oct 29 | 7 | 7 | 0 | 14 | 1 | 0 | 0 | 1 |
| Oct 31[d] | 2 | 8 | 0 | 10 | | | | 0 |
| Nov 1[d] | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| Nov 4[d] | 19 | 14 | 1 | 34 | 1 | 1 | 0 | 2 |
| Nov 7[d] | 1 | 3 | 1 | 5 | | | | 0 |
| Nov 8 | 9 | 10 | 0 | 19 | | | | 0 |
| Nov 13 | | | | 0 | | | | 0 |
| Nov 14 | 0 | 5 | 0 | 5 | 0 | 1 | 0 | 1 |
| Nov 15[d] | 1 | 2 | 0 | 3 | | | | 0 |
| Nov 18[d] | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 1 |
| Nov 20 | 1 | 3 | 0 | 4 | | | | 0 |
| Nov 21 | | | | 0 | | | | 0 |
| Nov 25 | 3 | 7 | 0 | 10 | 0 | 1 | 0 | 1 |
| Nov 29 | 0 | 1 | 0 | 1 | | | | 0 |
| Dec 4 | 2 | 8 | 0 | 10 | 0 | 1 | 0 | 1 |
| Dec 5 | 0 | 2 | 0 | 2 | | | | 0 |
| Dec 6[d] | | | | 0 | | | | 0 |
| Total | 45 | 73 | 2 | 120 | 2 | 6 | 0 | 8 |
| Area 1B[c] | | | | | | | | |
| Oct 23 | 1 | 0 | 0 | 1 | | | | 0 |
| Oct 28 | 12 | 5 | 0 | 17 | 2 | 1 | 0 | 3 |
| Oct 29 | 4 | 2 | 0 | 6 | 1 | 0 | 0 | 1 |
| Oct 31[d] | 32 | 17 | 1 | 50 | 4 | 3 | 1 | 8 |
| Nov 1[d] | 39 | 25 | 6 | 70 | 4 | 1 | 0 | 5 |
| Nov 4[d] | 25 | 25 | 1 | 51 | 5 | 3 | 0 | 8 |
| Nov 7[d] | 27 | 37 | 1 | 65 | 6 | 6 | 0 | 12 |
| Nov 8 | 33 | 31 | 2 | 66 | 3 | 1 | 0 | 4 |
| Nov 13 | 49 | 60 | 5 | 114 | 7 | 4 | 1 | 12 |
| Nov 14 | 2 | 7 | 0 | 9 | 0 | 1 | 0 | 1 |
| Nov 15[d] | 11 | 12 | 0 | 23 | 2 | 1 | 0 | 3 |
| Nov 18[d] | 18 | 23 | 0 | 41 | 3 | 1 | 0 | 4 |
| Nov 20 | 1 | 3 | 0 | 4 | | | | 0 |
| Nov 21 | 9 | 10 | 0 | 19 | 2 | 2 | 0 | 4 |
| Nov 25 | 2 | 4 | 0 | 6 | 0 | 1 | 0 | 1 |
| Nov 29 | 5 | 12 | 0 | 17 | 2 | 0 | 0 | 2 |
| Dec 4 | 12 | 7 | 0 | 19 | | | | 0 |
| Dec 5 | | | | 0 | | | | 0 |
| Dec 6[d] | 5 | 9 | 0 | 14 | 1 | 3 | 0 | 4 |
| Total | 287 | 289 | 16 | 592 | 42 | 28 | 2 | 72 |

[a] M = Male; F = Female; J = Jack

[b] One male included here was not included in Table 7.

[c] See Figure 1 for area locations.

[d] Diving surveys were conducted in the lower Campbell River.

Appendix 8. Dead recovery and adipose clip recovery in the Quinsam River, 1985.

| Date | Total recovered[a] | | | | | Adipose clipped recovered | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | J | U | Total | M | F | J | U | Total |
| Area 2B[b] | | | | | | | | | | |
| Oct 30 | 1 | 8 | 0 | | 9 | 0 | 2 | 0 | | 2 |
| Nov 5 | 20 | 21 | 1 | | 42 | 8 | 2 | 0 | | 10 |
| Nov 6[c] | | | | | 0 | | | | | 0 |
| Nov 7 | | | | | 0 | | | | | 0 |
| Nov 11 | 18 | 18 | 0 | | 36 | 6 | 4 | 0 | | 10 |
| Nov 12[c] | | | | | 0 | | | | | 0 |
| Nov 14 | 8 | 13 | 1 | 2 | 24 | 0 | 0 | 0 | 2 | 2 |
| Nov 15 | | | | | 0 | | | | | 0 |
| Nov 19 | 3 | 9 | 0 | | 12 | 0 | 2 | 0 | | 2 |
| Nov 20 | | | | | 0 | | | | | 0 |
| Nov 22 | 3 | 1 | 0 | | 4 | 1 | 1 | 0 | | 2 |
| Nov 25 | 0 | 3 | 0 | | 3 | 0 | 1 | 0 | | 1 |
| Nov 26 | 0 | 1 | 0 | | 1 | | | | | 0 |
| Nov 27 | | | | | 0 | | | | | 0 |
| Dec 2 | 4 | 5 | 0 | | 9 | | | | | 0 |
| Dec 3 | | | | | 0 | | | | | 0 |
| Dec 5 | 0 | 1 | 0 | | 1 | | | | | 0 |
| Dec 11 | 3 | 9 | 0 | | 12 | 0 | 4 | 0 | | 4 |
| Dec 12 | | | | | 0 | | | | | 0 |
| Dec 5 | | 1 | (Sec 28) | | 1 | | | | | |
| Total | 60 | 90 | 2 | 2 | 154 | 15 | 16 | 0 | 2 | 33 |

| Date | Total recovered[a] | | | | | Adipose clipped recovered | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | J | U | Total | M | F | J | U | Total |
| Area 2C[b] | | | | | | | | | | |
| Oct 30 | 11 | 18 | 0 | | 29 | 1 | 6 | 0 | | 7 |
| Nov 5 | 16 | 16 | 2 | | 34 | 3 | 2 | 1 | | 6 |
| Nov 6[c] | 31 | 62 | 2 | | 95 | 11 | 16 | 1 | | 28 |
| Nov 7 | 16 | 22 | 2 | | 40 | 4 | 3 | 0 | | 7 |
| Nov 11 | 31 | 58 | 4 | | 93 | 10 | 10 | 0 | | 20 |
| Nov 12[c] | | | | | 0 | | | | | 0 |
| Nov 14 | 5 | 17 | 2 | 11 | 35 | 2 | 3 | 1 | 11 | 17 |
| Nov 15 | 4 | 4 | 0 | | 8 | 1 | 1 | 0 | | 2 |
| Nov 19 | 14 | 20 | 2 | | 36 | 2 | 5 | 0 | | 7 |
| Nov 20 | | | | | 0 | | | | | 0 |
| Nov 22 | 29 | 38 | 1 | | 68 | 13 | 8 | 0 | | 21 |
| Nov 25 | 5 | 3 | 0 | | 8 | 1 | 0 | 0 | | 1 |
| Nov 26 | 2 | 1 | 0 | | 3 | 1 | 0 | 0 | | 1 |
| Nov 27 | | | | | 0 | | | | | 0 |
| Dec 2 | 16 | 15 | 2 | | 33 | 7 | 4 | 1 | | 12 |
| Dec 3 | | | | | 0 | | | | | 0 |
| Dec 5 | | | | | 0 | | | | | 0 |
| Dec 11 | 3 | 6 | 0 | | 9 | 1 | 2 | 0 | | 3 |
| Dec 12 | | | | | 0 | | | | | 0 |
| Dec 5 | | | | | | | | | | |
| Total | 183 | 280 | 17 | 11 | 491 | 57 | 60 | 4 | 11 | 132 |

| Date | Total recovered[a] | | | | | Adipose clipped recovered | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M | F | J | U | Total | M | F | J | U | Total |
| Area 2D[b] | | | | | | | | | | |
| Oct 30 | | | | | 0 | | | | | 0 |
| Nov 5 | 55 | 52 | 5 | | 112 | 10 | 5 | 2 | | 17 |
| Nov 6 | 10 | 3 | 0 | | 13 | 3 | 1 | 0 | | 4 |
| Nov 7 | | | | | 0 | | | | | 0 |
| Nov 11 | 13 | 2 | 1 | | 16 | 6 | 1 | 1 | | 8 |
| Nov 12 | 29 | 18 | 0 | | 47 | 7 | 3 | 0 | | 10 |
| Nov 14 | 1 | 1 | 0 | | 2 | | | | | 0 |
| Nov 15 | 23 | 20 | 0 | | 43 | 6 | 2 | 0 | | 8 |
| Nov 19 | 11 | 12 | 0 | | 23 | 3 | 0 | 0 | | 3 |
| Nov 20 | 8 | 7 | 0 | | 15 | 1 | 2 | 0 | | 3 |
| Nov 22 | 11 | 9 | 0 | | 20 | 6 | 2 | 0 | | 8 |
| Nov 25 | | | | | 0 | | | | | 0 |
| Nov 26 | 7 | 7 | 1 | | 15 | 2 | 2 | 0 | | 4 |
| Nov 27 | 6 | 2 | 1 | | 9 | 5 | 0 | 0 | | 5 |
| Dec 2 | | | | | 0 | | | | | 0 |
| Dec 3 | 9 | 7 | 2 | | 18 | 2 | 2 | 0 | | 4 |
| Dec 5 | | | | | 0 | | | | | 0 |
| Dec 11 | | | | | 0 | | | | | 0 |
| Dec 12 | 8 | 2 | 0 | | 10 | 2 | 0 | 0 | | 2 |
| Dec 5 | | | | | | | | | | |
| Total | 191 | 142 | 10 | 0 | 343 | 53 | 20 | 3 | 0 | 76 |

[a] M = Male; F = Female; J = Jack; U = Unknown

[b] See Figure 1 for area locations.

[c] Diving surveys were conducted in deeper pools throughout Quinsam River.